VARIATION AND COVARIATION IN BIRTHCOAT AND FLEECE TRAITS OF DRYSDALE SHEEP WITH REFERENCE TO EARLY SELECTION AND SAMPLING POSITIONS

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ABSTRACT

Samples from different body regions were obtained from the birthcoat, first, second and third fleeces of sheep in two Drysdale flocks. Fibre type arrays of birthcoat samples were analysed and various wool traits were assessed and measured in samples obtained at three shearings.

Sampling position was the main source of variation in most traits studied. Sex, birth rank, and age of dam generally made little contribution to the total variance. Shearing, flock and sire effects were also important sources of variation for many traits. The interaction of shearing X position and the interactions of sire with each of shearing, sex and birth rank were significant for many traits.

Phenotypic correlations among fleece traits were estimated from shoulder and mid-side positions as well as among fleece averages calculated from all positions. Correlations among fleece averages showed that higher kemp score (KS) was associated with higher bulk; BUL (0.24 to 0.64), resilience; RES (0.03 to 0.48) and tristimulus colour values; X, Y and Z (0.08 to 0.46). Softer handle grade tended to be correlated with lower BUL (-0.22 to -0.66) and RES (-0.16 to -0.53) and higher lustre; LG (0.10 to 0.62). Higher medullation index (MI) was generally associated with higher BUL (-0.15 to 0.49) and tristimulus colour values (-0.01 to 0.60) and lower LG (-0.65 to 0.08). Correlations among tristimulus colour values were the highest between X and Y reflectances (0.93 to 1.00). Greasy and clean wool per unit area (GWA and CWA) were highly correlated (0.93 to 0.96). Heavier first greasy fleece weight (GFW1) correlated positively with GWA (0.59) and CWA (0.56). Staple length (STL) tended to be longer as GWA (0.37 to 0.60), CWA (0.39 to 0.60) and GFW1 (0.64) inceased and as BUL decreased (-0.01 to -0.54). BUL and RES were highly correlated (0.82 to 0.95). LG was negatively correlated with BUL (-0.12 to -0.66) and RES (-0.10 to -0.41).

Very few sickle fibres were found in Drysdale materials; most arrays were plateau. Coarser arrays were associated with higher proportions of hairy-tip curly-tip fibres (HTCT). GFW1 increased as HTCTs increased (0.33 to 0.46). Generally, the correlations among birthcoat and third fleece traits were not strong which implies that birthcoat traits are not reliable indications to selection for various traits in later fleeces of Drysdale sheep. Higher MI was associated with coarser arrays (-0.07 to -0.55) and higher proportions of super-sickle A fibres (0.22 to 0.41). Finer arrays were associated with higher yield (0.01 to 0.38). In one flock, sheep with a higher proportion of halo-hair (HH) fibres had higher GWA (0.25 to 0.33), CWA (0.17 to 0.30) and heavier third fleece weights (0.09 to 0.33) while sheep with coarser birthcoat arrays showed a slight tendency to have more bulky fleeces (-0.22 to -0.29).

Medullation index of the third fleece (MI3) as well as greasy and clean third fleece weights (GFW3 and CFW3) can be predicted, with limited accuracy ($R^2 = 0.50$) from the first shearing shoulder (SH1) traits by using the following multiple regression equations:

Within flock-sex groups

$$MI3 = 9.15 + 0.45MI\ (SH1) + 1.84KS\ (SH1)$$

For rams

$$GFW3 = -1.47 + 0.04HH\%\ (SH1) + 0.14X\ (SH1) - 0.09Z\ (SH1)$$

$$CFW3 = -1.53 + 0.03HH\%\ (SH1) + 0.14X\ (SH1) - 0.09Z\ (SH1)$$

It appeared that the shoulder is the best position from which to sample fleeces when a number of traits are to be assessed for ranking Drysdale sheep.

GENERAL INTRODUCTION

Systematic selection and culling of sheep to improve the quantity and quality of wool produced has been practised for many generations. A careful analysis of the fleece is usually first made on the hogget fleece when often many animals have already been culled. Birthcoat fibre type array analyses have been suggested as an early indication of adult fleece traits. The present study investigated the use of birthcoat fibre type arrays as an aid to early selection for various fleece traits. The variations of adult fleece traits were also studied in Drysdale fleeces.

It is important to determine the optimum position for sampling wool traits when assessment of these samples is to be used for selection. Very few studies dealt with that subject. These studies defined the best sampling position as the most representative to the whole fleece. The present study expanded this definition to also consider utility for breeding purposes in an attempt to reach an overall decision of what is the best sampling position for Drysdale sheep.

Phenotypic correlation coefficients among various wool traits were calculated from shoulder and mid-side samples in the three shearings. These correlations were derived to gain some information on the use of these samples to predict the average of the present fleece and later fleeces. These correlations are presented in Appendix 2.

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LIST OF ABBREVIATIONS

1. Positions

BK	back
BL	belly
BR	britch
MS	mid-side
RP	rump
SH	shoulder
SP	shoulder patch
WH	withers

2. Shearings

FL1	first shearing
FL2	second shearing
FL3	third shearing
Av	average of the fleece
Av1	average of the first fleece
Av2	average of the second fleece
Av3	average of the third fleece

3. Traits

a) Birthcoat traits

ARY	birthcoat fibre type array
Ch-CT	checked curly-tip fibres
CT	curly-tip fibres (CT1 + CT2)
CT1	the coarsest curly-tip fibres
CT2	the thinnest curly-tip fibres
F-SK	fine sickle-fibres
HH	halo-hair fibres
Hi	histerotrich fibres
HTCT	hairy-tip curly-tip fibres (HTCT1 + HTCT2)
HTCT1	the coarsest hair-tip curly-tip fibres
HTCT2	the thinnest hairy-tip curly-tip fibres
Pre-CT	pre-curly-tip fibres (HH + SS + SK + F.SK)

Abbreviations continued.

SK	sickle fibres
SS	super-sickle fibres (SSA + SSA' + SSB)
SSA	super-sickle A fibres
SSA'	super-sickle A' fibres
SSB	super-sickle B fibres

b) fleece traits

BUL	bulk
CWA	clean wool per unit area
CFW3	clean third fleece weight
GCG	greasy colour grade
GFW1	greasy first fleece weight
GFW3	greasy third fleece weight
GWA	greasy wool per unit area
HG	handle grade
KS	kemp score
LG	lustre grade
MI	medullation index
RES	resilience
SCG	scoured colour grade
STL	staple length
X	tristimulus X value (red)
Y	tristimulus Y value (green)
YLD	yield
Z	tristimulus Z value (blue)

CHAPTER 1

VARIATION AND COVARIATION IN BIRTHCOAT AND FLEECE TRAITS OF DRYSDALE SHEEP WITH REFERENCE TO EARLY SELECTION

1.1 INTRODUCTION

The extensive work of Dr. F.W. Dry and his co-workers (Dry, 1975) led to the identification of the *N*-gene in New Zealand Romney sheep and eventually to the development of a breed of sheep homozygous for this gene, the Drysdale. The merits of the Drysdale wool for carpet manufacture were investigated in extensive processing trials (Nash, 1964; Ross, 1970; Ross *et al.*, 1975; Nandurkar and Lappage, 1977). These trials confirmed the utility of Drysdale wool in carpet wool blends. Similar genetic procedures were also used to develop other speciality carpet-wool breeds such as Tukidale and Carpetmaster (Wickham, 1978).

Birthcoat fibre type arrays (Dry, 1935) may be useful for predicting the characteristics of subsequent fleeces. Scant data are available on the relationship between birthcoat fibre type arrays and adult fleece measurements. While there are indications that finer birthcoat arrays tend to be followed by less kemp in the adult fleece, sufficient information on the relation between birthcoat and adult fleece traits is lacking.

The evaluation of Drysdale wool traits has not been studied thoroughly. This exploratory study was initiated to investigate the use of birthcoat fibre type arrays as an aid to early selection for some adult fleece traits in Drysdale sheep and to gain some knowledge of sources of variations in the characteristics of Drysdale fleeces.

1.2 REVIEW OF LITERATURE

1.2.1 Carpet Wool Traits: Their Importance Particularly in Relation to Manufacture and Selection Objectives

1.2.1.1 The commercial importance of carpet wool traits

The effects of varying levels of various wool traits on the processing performance of carpet wool have not been well defined (Ross *et al.*, 1982). Definition of desirable carpet wool traits is difficult, partly because carpets are made from various blend components the proportions and prices of which differ considerably from region to region throughout the world (Turner and Dunlop, 1974; Ross *et al.*, 1982). There have been very few trials studying the effect of different fibre characteristics on carpet processing and performance. Much of the experimental processing data comes from trials where selected unblended lines have been processed (Nash, 1964; Nandurker and Lappage, 1977). The interpretation of these trials' results is complex according to Wickham (1977) since commercial carpets are made from blends and the trials have usually been carried out to investigate certain specific traits of unblended lines. Wickham (1977) discussed the difficulty of deciding whether a characteristic which is important for one type of carpet or a certain processing system is equally important in different circumstances. Hunter (1980) suggested an approach in which the processing should be based on a large number of representative samples of a population with the effects of the various traits being separated statistically.

A. Length

Staple length plays an important role in determining the price of wool likely to be used in carpets (McPherson, 1982; Elliott, 1984). Ross (1978b) stated that staple and fibre length are of more concern to the carpet industry than mean fibre diameter. However, Ince and Ryder (1984) stated that although fibre length is important for yarn preparation, it had no effect on either yarn properties or carpet performance. Fibre length after carding is an important criterion to manufacturers. An estimate of the expected fibre length after carding can be obtained from staple length, staple strength and break level

(Ross, 1982). Staple length is a convenient and traditional way of measuring length in raw wool but it can not be used after carding since this process breaks up the staples.

An increase in fibre length generally reduces yarn hairiness (Onions *et al.*, 1967; Srivastava *et al.*, 1976), produces a stronger and less extensible yarn (Ince, 1978) and improves abrasion resistance (Barella and Vigo, 1979, cited by Hunter, 1980). Shorter fibres produce thicker (bulkier) and more compressible yarns (Onions *et al.*, 1967). Ross (1978a) stated that the New Zealand carpet manufacturers generally require staple lengths of 50-125 mm for woollen processing and of 75-175 mm for semi-worsted yarns. Short fibres under 50 mm cause shedding problems, especially in cut-pile carpets. Very long fibres cause processing problems on the woollen cards and decrease yarn bulk. Similar conclusions have been reached by the Australian carpet industry (Bell, 1981).

B. Medullation and fibre diameter

The wools which have traditionally been preferred for carpet manufacture contain many medullated fibres. These are generally coarser and stiffer than non-medullated fibres (Burns *et al.*, 1940; Turner and Dunlop, 1974; Wickham, 1977). Although the carpet manufacturers require considerable medullation, the specification for optimal fibre diameter and percentage medullation do not exist (Turner and Dunlop, 1974; Ross, 1978a; Bell, 1981; Ross *et al.*, 1982) and the exact role of medullation is not clear (Ross *et al.*, 1982).

Fibre diameter alone has very little effect on either the laboratory or the floor performance of carpets (Ross, 1978a; Ince, 1978). The position of fibres in the yarn depends on their diameter and length; coarser and shorter fibres tended to be further away from the yarn axis (Carnaby and Grosberg, 1976; Carnaby, 1979), thus affecting handle and appearance. An increase in fibre diameter increased yarn hairiness (Ross, 1978a; Carnaby, 1978).

New Zealand manufacturers prefer higher mean fibre diameter, 36μ or higher (Ross, 1978a) because they believe that coarser fibre diameter was associated with sounder wool, higher yarn yields, more medullation, crisper handle, higher abrasion resistance and lower pile flattening or better resilience (Ross, 1978a; Carnaby *et al.*, 1984). Carpets made from coarse and medullated wool were considered to retain their appearance better than carpets made from fine wool (Ross, 1978a).

In Indian carpet wools, Sule (cited by Turner, 1976) suggested that a carpet wool should have at least 20% of the fibres with interrupted medulla but not more than 10% of the fibre in which the medulla made up more than 60% of the diameter. While at least 40% of the fibres should be non-medullated, kemp fibre should be no more than 2%.

A proportion of medullated wool is often desirable in the carpet blend, the actual proportion depending on the processing system and the end product (Ross, 1978a). Anderson and Clegg (1963) reported that increased carpet wear rates were associated with a higher proportion of heavily-medullated fibres.

Medullated wools will produce more hairy and bulky yarns (Elliott and Carnaby, 1980) and usually with better cover for less weight (Ince, 1978). Medullation also gives a natural look and is thought to improve the appearance retention of carpets (Ross, 1978a). For semi-worsted processing and for loop-pile carpets a smaller proportion of medullated wool is included in the blend. Ross (1978a) listed some disadvantages of medullated fibres. They are generally poorer spinning and result in lower yarn yields. They have an effect on dyeing and colouration; highly-medullated wool appears to dye to a paler colour than non-medullated wool owing to light reflection from the cortex-medulla interface (Nandurkar and Lappage, 1977; Ince, 1979). It was also stated by Ross (1978a) that wide variability is associated, in some wool, with a crimpy short fine undercoat and coarse medullated outercoat fibres. These types are desirable in carpet blends; the finer fibres help spinning and yarn bulk, the coarser fibres give the desired handle and appearance. High variability, however, is not usually desired for semi-worsted yarns or for loop-pile carpets (Ross, 1978a).

Medullation can be detected by eye or hand. A method of measuring medullation was developed by Elphick (1932) and McMahon

(1937). Elphick observed that the refractive indices of benzol and the keratin of the cortex of wool fibres are very similar. Consequently, when non-medullated fibres are immersed in benzene they become invisible, whereas medullated fibres which contain an air-filled medulla appear white under similar treatment. McMahon was able to measure the light reflected from the medulla by means of a photo-electric cell in an instrument known as a medullameter which he developed. The light reflected was a linear function of the volume of medulla in the fibre. Ross (1950) found a correlation of 0.94 between the medulla area per unit weight and the photoelectric index. Ross and Speakman (1957) suggested that the amount of light scattered by medulla in the McMahon instrument should be proportional to the surface area of the medulla rather than its volume. Lappage and Bedford (1983) developed a new version of the medullameter giving medullation index calibrated against the percentage area of medulla measured by projection microscope. Ross (1978a) suggested that expressing the level of medullation in terms of the percentage of medullated fibres can be misleading, since the percentage of medullated fibres as well as the medulla to cortex ratio differed enormously.

C. Kemps

These are shed fibres, short and heavily-medullated. While long and continuously-medullated fibres are desirable in carpet wool, too many very coarse fibres with little cortex in the cross-section can have adverse effects especially when fibre strength and elasticity are required (Ross, 1978a; Ross *et al.*, 1982). Kemps tended to break during processing resulting in increased wastage during carding and spinning, and because of their dyeing properties they may give an undesirable appearance in the finished carpet (Ross, 1978a). Kemps also tended to lie on the outside of the yarn and resulted in harsh handle (Carnaby, 1979).

D. Bulk or resistance to compression (RTC)

Van Wyke (1946) laid the foundation for understanding the behaviour of wool subject to compression. He suggested that RTC is mainly a function of the product of staple crimp frequency and fibre diameter. Chaudri and Whiteley (1968) subsequently found that the product of fibre diameter and crimp frequency can explain 89% of the variation in RTC. They also indicated that fibre crimp is the most important single trait influencing RTC and higher RTC is associated with helical type crimp compared with planar types. Ince (1979), Carnaby and Elliott (1980) and Ince and Ryder (1984) showed similar findings for loose wool bulk which is closely related to RTC (Dunlop *et al.*, 1974).

Differences in yarn bulk are largely due to differences in loose wool bulk (Ince, 1976, 1979; Carnaby and Elliott, 1980; Elliott and Carnaby, 1980). Ross (1978a) stated that a wide range of loose wool bulk (19-33 cm^3/g) was found to cover a very narrow range in carpet performance. Ince and Ryder (1984) showed that fibre crimp gave better spinnability and improved covering power in the carpet wool. Bulky wool would produce bulky yarns and carpets with preferred appearance and with higher covering power; however, it would decrease breaking strength and extension (Ince, 1979; Elliott and Carnaby, 1980; Carnaby *et al.*, 1984).

E. Colour

Unscourable discolouration is a significant factor in determining the value of the wool (Hoare, 1974; McPherson, 1982). It affects dyeing characteristics since the production of bright light shades and superior whiteness on wool requires the use of pure white wool which can be readily dyed to any other colour (Von Bergen, 1963; Hoare, 1974). The presence of black or pigmented fibres in white tops or yarns is a serious and expensive defect creating problems in dyeing of light shades (Sullivan, 1979; cited by Hunter, 1980).

F. Soundness

Modern high-speed processing machinery is placing additional stresses on the fibre and, therefore, demands sound wool (Ross, 1978a; Bigham *et al.*, 1983b). While all wools suffer some degree of fibre breakage during processing, sound wools generally result in less breakage compared with tender wools (Ross *et al.*, 1960; Von Bergen, 1963; Bratt *et al.*, 1964; Ross, 1982).

Orwin *et al.* (1980) and Bigham *et al.* (1983) suggested that the intrinsic fibre strength of tender wool was lower than that of sound wools. Orwin *et al.* (1980) also reported that differences in composition as well as in diameter influence fibre strength. Processing performance has been found to be poorer for a wool with a tender region near the middle of the staple compared to one with a tender region near the end (Ross *et al.*, 1960; Bratt *et al.*, 1964). Staple length and strength combined should provide a good prediction of fibre length in the top for "average" processing conditions (Downes, 1975). Bigham *et al.* (1983b) reported that the stronger yarn is primarily related to the longer mean fibre length in the yarn. It can be expected that yarn strength will be proportional to fibre strength (Bratt, 1965; Holdaway, 1965). Such manufacturing significance might partly explain why tender wools usually suffer price discount (Wiggins, 1976; Wickham and Bigham, 1976; McPherson, 1982).

G. Cotting

Cotting is the result of fibres being shed from their follicles and migrating through the fleece causing entanglement with other fibres (Joyce, 1961; Wickham, 1973; Wickham and Bigham, 1976). Cotted wool must be teased apart; a process involving higher cost and some deterioration in wool value due to fibre damage (Joyce, 1961). Cotting can result in damage to processing equipment (Ross, 1978a; Bell, 1981). consequently there is quite a marked price discount for cotted wool (Joyce, 1961; Wickham, 1973; Wickham and Bigham, 1976; McPherson, 1982).

H. Lustre

Lustre is generally thought to be undesirable in carpet wools as higher-lustre wool tends to be associated with low bulk and resilience (Wickham, 1973; NZSAP, 1974; Wickham and Bigham, 1976; Ross, 1978a; Bell, 1981). However, some processors like to buy lustrous wool since it enables them to produce brighter colours in the end products (Wickham and Bigham, 1976; Larsen, 1978). Nandurkar and Lappage (1977) carried out a processing trial including wools from the progeny of fine, coarse-plain and lustrous Romney ewes crossed with Drysdale rams. The fleeces from each group were sorted into three commercial types of Drysdale wool: coarse, medium and fine. They found that the fine component of the fleeces from the progeny of the lustrous-woolled ewes had sufficient lustre for this to be apparent in the final carpet.

1.2.1.2 Selection objectives in carpet-woolled sheep

For success in a sheep breeding policy, a clear definition of selection objectives is necessary. James (1982), Morris *et al.* (1982), and Wickham and McPherson (1985) showed the difference between selection objectives and selection criteria. The former is what the breeder seeks to improve while selection criteria are the traits which are considered at selection time.

Very few studies have discussed the role of different wool traits in sheep breeding objectives of speciality carpet wool breeds. Turner and Dunlop (1974), NZSAP (1974), Turner (1976), Morris *et al.* (1982), Rae (1982) and Ross *et al.* (1982) raised some difficulties involved in formulating and defining selection objectives for speciality carpet wool breeds; some of these were:

1) the specifications of speciality carpet wool traits required by the manufacturers are difficult partly because carpets are made from various blend components the proportions and prices of which differ considerably;
2) fashions and technical changes in the textile industry may alter the relative economic values of traits in the breeding objectives;
3) as many traits contribute to the sheep's profitability (meat, milk and lamb production), selection for improved overall sheep performance will limit the scope to select for wool traits.

While, in theory, each trait of economic importance which is able to respond to selection must be included in a breeding objective (Gjedrem, 1972; Morris *et al.*, 1982) estimates of the economic and genetic parameters of many carpet wool traits are not available or are of limited usefulness.

The studies of speciality carpet wool breeding objectives concluded that the first priority is high fertility as this will result in the greatest increase in profitability and predetermine the amount of genetic progress in other traits. Fleece weight should be the main wool selection objective with improvement of bulk, whiteness and medullation being next in importance.

Greasy or clean fleece weight was accepted as the major selection objective for both carpet and apparel wool production (Turner and Dunlop, 1974; NZSAP, 1974; Bigham, 1975; Turner, 1976; Morris *et al.*, 1982; Rae, 1982; Ross *et al.*, 1982; Whiteley and Jackson, 1982). Wickham (1966, 1973) examined wool traits more closely and concluded that selection for increased fleece weight is the most efficient way of influencing the profitability of wool production.

Processing trials indicated that raw wool bulk is of importance in carpets (Carnaby and Elliott, 1980). However, Elliott (1984) showed, in Perendale wool, that price premiums paid for bulk alone were neither large nor consistent compared with fineness or staple length. Bigham *et al.* (1983a) indicated that selection for loose wool bulk would not be to the breeder's advantage as it would reduce clean fleece weight.

White colour is desirable as this is a significant factor in determining the value of the raw wool (Hoare, 1974; McPherson, 1982). There is some evidence that selection on visual estimates of colour in greasy wool can be effective (Chopra, 1978). Bigham *et al.* (1983a) revealed that selection for reduced Y-Z, as yellowness index, would reduce fleece weight, consequently it would not be to the breeder's advantage.

In speciality carpet wools there is a need for a considerable amount of medullation (Turner, 1976; Morris *et al.*, 1982; Rae, 1982; Ross *et al.*, 1982). However, too many very coarse medullated fibres may reduce yarn strength and elasticity. In Drysdale sheep, it is believed that the level of medullation achieved is already adequate (Morris *et al.*, 1982; Rae, 1982; Ross *et al.*, 1982). Consequently, it was concluded that the level of medullation should be maintained, kemps should be largely eliminated and the proportion of very heavily medullated fibres reduced.

1.2.2 The Morphology and Inheritance of the Birthcoat

1.2.2.1 Birthcoat fibre type arrays

Toldt (1910, 1912, 1935, cited by Wickham, 1963) separated the individual fibre types produced by many mammals into different classes; outer thick hair, over hair and fine hairs. Duerden and Seale (1927) drew attention to sickle fibres, so named after the shape of their tips. A description of the lamb's birthcoat fibres was first published by Duerden (1929). Duerden and Boyd (1930) described the birthcoat fibres of the Merino and Persian Blackhead lambs, defining in particular the sickle fibre. They attributed this tip shape to the mechanical effect of the fibre forcing its way out of the skin when it was first formed. They also described the thinning of the fibres at the birth point; they attributed this to the changed physiological status of the lamb at birth.

The major descriptive work on the lamb's fleece has been due to Dry (1935) who developed a morphological classification of the birthcoat fibre types found in New Zealand Romney lambs. This classification was based on the shape of the fibre tip with further subdivision according to the presence or absence of a medulla in various regions of the fibre. The features of different birthcoat fibre types are detailed in Section 1.3.2. Dry (1935) also classified birthcoat samples into fibre type arrays on the presence or absence of certain fibre types. These arrays were described also by Stephenson (1956) and presented in Table 1.3.1. Dry (1935) theorised that the fibre type arrays resulted from varying intensities of prenatal check which he defined as "an inhibiting force tending to fineness and the prevention of medullation." He suggested that the persistent growth of wool fibres may be also due to this force. Dry postulated that the prenatal check is sufficient to cause variations between and within the fibre type arrays. Sutherland (1939) studied the variation within the plateau array, and suggested a further factor "base", an inherent drive towards coarseness and medullation. Thus the fibre type array was the result of two independent but interacting forces: the prenatal check and base. These two forces acted antagonistically to each other, a strong base resulting in coarse medullated fibres which could withstand a fairly intense prenatal check. Dry (1940) indicated that, in plateau arrays, the prenatal check was not able to convert any of the Pre-CT fibres into sickles. He suggested that the strong base is more important than weak prenatal check in making the array plateau. However, in saddle arrays, while the prenatal check was able to produce sickle fibres it was not powerful enough to cause any of these fibres to remain fine after birth.

Ross (1950) measured fibre length and fibre diameter of birthcoat samples and showed that coarse arrays were associated with high variability of fibre diameter and a trimodal fibre length distribution.

A highly significant correlation (0.75) between the fibre type array and medullameter test reading was reported by Goot (1945). Stephenson (1956) measured the hairiness of the birthcoat samples by the medullameter test and stated that the results of fibre type arrays were similar to those of the medullameter test. He showed that the effect of the prenatal check was smallest in plateau arrays and greatest in plain arrays. Stephenson (1956) also showed that fine sickle and checked curly-tip fibres were more frequent when birthcoat hairiness is low. SSA, SSA' and SK fibres are of intermediate hairiness and very strong medullated fibres (HH and HTCT) increased in abundance with increasing hairiness of the birthcoat.

A. Variation over the body

The variation in the fibre type arrays over the body was first studied by Galpin (1935, 1936) in New Zealand Romney, Southdown and Ryeland lambs. Despite the great variations found among individuals, she showed a gradient in hairiness in which the most hairy arrays were found on the britch and the least hairy on the poll. She attributed this to a britch-to-poll increase in the prenatal check. Similar findings were reported in different *N*-genotypes of New Zealand Romney (Stephenson, 1952, 1956) and in Kerry, Swaledale and Cheviot X Swaledale crosses (Guirgis, 1967). Stephenson (1952) also found that in order of coarseness, arrays ranked britch, back, side, withers, neck and shoulder. The most heavily checked sample found was from the shoulder patch. In Barki lambs, lateral positions tended to have more coarse arrays than those of the dorsal line (Elgabbas, 1978) but the trend was reversed in Awassi and Hamadani lambs (Guirgis, 1979).

Galpin (1935) and Stephenson (1952) showed that the proportion of Pre-CT fibres in arrays differed markedly among positions. Galpin added that higher levels of Pre-CT were found on the areas where the follicles established earliest. That was interpreted in terms of the onset of the prenatal check which might have occurred after the fibre had commenced growth in these regions of early-developing follicles. Elgabbas (1978) found highly significant position effects for all birthcoat fibre types, the position variance component contributing a range of 6-75% to the total variance in all fibre types.

Galpin (1935), Wickham (1958) and Side (1964) suggested that the prenatal check, as manifested in SK fibre morphology, does not occur simultaneously in all areas and that the prenatal check must affect individual follicles at different times on different positions. Wickham (1963) and Rudall and Wickham (1965) produced evidence that the prenatal check was not systemic in origin.

B. Theories explaining birthcoat fibre forms

Various theories to explain the development of birthcoat fibre types and arrays have been postulated; however, these theories have not been adequately tested.

Duerden and Boyd (1930) attributed the fibre thinning at the birth point to the changed physiological status of the lamb at birth. Dry (1935) expanded this idea into the prenatal check theory. The introduction of the 'base' concept by Sutherland (1939) also contributed to Dry's theory. Dry (1935) first suggested that the prenatal check was due to increasing follicle density in the skin. He further proposed that the prenatal check caused sub-apical thinning of halo-hair and sickle fibres, fineness of the prenatal region of curly-tip fibres and of the postnatal portions of fine sickle and checked curly-tip fibres and shedding of baby and infant fibres. He also suggested that the prenatal check inhibits fibre shedding and allows persistent growth of fibres at a lower level of activity.

Since the fibre was thought to have a constant crimp deflection per unit of time and if the fibre is being produced at a constant rate, a regular crimp wave would result. If the growth rate became slower the fibre would show a decreasing radius of curvature according to Duerden (1927). Dry (1935) attributed the formation of the sickle-end to the prenatal check. Galpin (1935) studied the prenatal development of the coat of New Zealand Romney lambs and suggested "trio-depression" occurred when each larger follicle acquired two small neighbouring follicles, one on either side, giving the trio arrangement. As the follicle density increased, she suggested a further check "nine-depression" in which each follicle in the original trio-group became the centre of a new trio-group giving the nine arrangement. Galpin proposed that these two variables (trio- and nine-depressions) caused the fibre to be fine thereafter. Galpin suggested that the interaction between these two variables would produce the different fibre type arrays. Fraser (1951, 1952a, b, 1953) and Fraser and Short (1952, 1960) formulated a theory of competition to account for the differences in fibre tip shapes. Fraser postulated that the newly-developing primary lateral follicles competed for fibre-forming substrates with the primary centrals. This caused a slowing of the growth rate of the primary central fibres. Thus the primary central follicles form fibres with a sickle-shaped tip whereas the lateral follicles form fibres with a regular curled-tip. Fraser and Hamada (1952) and Fraser *et al.* (1954) considered Pre-CT fibres to be produced by primary central follicles, and in plateau arrays, the primary laterals produced HTCT fibres while secondaries produced CT and Hi fibres. Wickham (1958), Burns (1966) and Guirgis *et al.* (1981a, b) have demonstrated that Pre-CT fibres may grow in primary lateral follicles and that fibres of the curly-tip group may grow in primary central follicles which invalidates the theory that competition from developing primary lateral follicles is the cause of the sickle-end formation.

Fraser (1951, 1952a, b) supposed that the follicles have different efficiencies to compete for fibre-forming substrates. He suggested that the prenatal check related the efficiency of a follicle to the follicle's time of development. On the other hand, Rendel (1954) considered the competition from secondary follicles to be a major determinant of adult fleece structure. He suggested that differences between fleece types are due to variation in the number of secondary fibres grown postnatally.

Stephenson (1958) found that the follicle density during prenatal life reached a maximum about the time when the prenatal check must occur. However, his data failed to reveal differences in density at any stage of foetal development which could explain the difference in the intensity of the prenatal check between *N* and non-*N* genotypes. It was also difficult to explain different intensities of the prenatal check between different regions in terms of the changes in follicle density at different foetal ages. Wickham (1963) also found fibres like sickles in skin grafts where the follicle density was very low.

Goot (1940) proposed that the prenatal check is an inherent property of individual follicles. Rudall (1955) studied the relationship between the shape of the papilla and fibre morphology. He showed a reduction in the height of follicles papillae producing checked sickle fibres as compared to non-checked curly-tip fibres, the follicle bulb diameter being the same for the two groups. Rudall ascribed this shortening to the action of the prenatal check. Derbyshire (1975) attributed a reduction in follicle bulb diameter to the prenatal check.

What the prenatal check is and how it works is still an obscure question.

1.2.2.2 Genetic effects on halo hair abundance and birthcoat fibre types and arrays

A birthcoat grading system based on abundance of halo-hairs was devised for New Zealand Romney lambs (Dry, 1940; Dry *et al.*, 1940; Dry and Fraser, 1947; Dry, 1955a; Stephenson, 1956). The grades varied from I (no halo-hairs) to VII (dense).

Dry and his colleagues were able to identify two major genes in New Zealand Romney sheep using this grading system (Dry, 1940; Dry *et al.*, 1940; Dry and Fraser, 1947; Dry, 1955b, c), the dominant *N* and the recessive *nr* gene. Dry and Fraser (1947) gave a method of distinguishing phenotypically between homozygous and heterozygous dominant *N*-type lambs. The shoulder patch region almost invariably had reduced HH abundance in *N*/+ lambs but *N*/*N* lambs were believed never to have a shoulder patch.

Schinckel (1951) suggested the presence of a major gene in the Australian Merino analogous to the gene in the New Zealand Romney. Subsequent data have raised doubts on the monogenic hypothesis (Schinckel, 1955). Multifactorial inheritance of HH abundance has been reported in Welsh Mountain sheep (Rendel, 1954) and in New Zealand Romneys which had neither the *N* or *nr* genes (Dry, 1955a). Wickham and Rae (1977) reported on other genes N^t and N^j allelic to the *N* gene (renamed N^d) of the Drysdale and the *n* gene of the Romney.

The main effect of the N^d gene is to increase the vigour and size of the early-developing primary follicles (Dry, 1940; Fraser, 1952b; Fraser *et al.*, 1954; Stephenson, 1958; Cockrem, 1963; Carter and Tibbits, 1959). This results in the increase of HH abundance, medullation, length of the coarsest fibres and greater fibre shedding as kemps. Dry (1940) and Dry and Fraser (1947) also reported the effect of the N^d gene on the production of horns.

Fraser (1952b) and Fraser *et al.* (1954) studied the birthcoat fibres and fibre growth rate up to 5 months. They concluded that the N^d and *n* genes caused an increase in the fibre output of the primary follicles and a decrease in output from the secondary follicles. Ross (1954) found that the most striking difference in the development of the coat between *N*-type and non-*N* type is the rapid rate of growth of follicles in the *N* type after the 92 days stage of foetal development. Stephenson (1959) pointed out that the first effect of the *N* gene is on the primary follicle papilla. This leads to an increased diameter of follicles and fibres. He also showed that the N^d gene has no effect up to 126 days conception, neither on follicle numbers nor on foetal growth.

Stephenson (1952) showed an increase in coarseness of the fibre type arrays with increasing dosage of N^d genes. The first increase in medullation was seen in the britch, back and side. With increasing N^d-gene dosage, this increase in coarseness spreads to other positions, finally producing a fairly uniformly coarse fleece. Stephenson (1952) also showed that in genotypes showing little hairiness, non-medullated fibres (fine sickle and checked CT) are the most common Pre-CT fibres. In N^d/N^d lambs the majority of fibres are HH, SSA and HTCTs.

Parent-offspring comparisons of fibre type arrays indicated that genetic factors are important in determining whether the array is plateau, saddle or valley (Dry, 1965). Burns (1972) stated that both prenatal check and base are essentially genetic but the intensity of the prenatal check can be modified by non-genetic factors acting during foetal development. In ova transfer experiments, it was suggested that the prenatal check of the transferred lambs was always in the direction of the prenatal check of the foster dam (Burns, 1972; Burns and Ryder, 1974). Guirgis (1977) reported that in reciprocal crosses between Merinos and Ossimis the prenatal check tended to that of the maternal breed.

1.2.3 Relationship of Lamb Traits to Other Traits

1.2.3.1 Birthcoat and survival

Lambs with coarser birthcoat grades have generally been found to have better survival, particularly in severe environmental conditions (Schinckel, 1955; Alexander, 1958; Purser and Karam, 1967; Obst and Evans, 1970; Semmens, 1971; McCutcheon, 1981). However, Mullaney (1966) found no relation between birthcoat grade and the survival of newborn Polwarth, Merino and Corriedale lambs. He concluded that although hairy-birthcoated lambs have certain physiological advantages they may have little survival advantages unless the weather is severe.

Alexander (1958) and Purser and Karam (1967) found that fine-coated lambs suffered very badly because of greater loss of body heat and energy reserves under severe conditions of low temperature, wind and rain. Slee (cited by Ryder, 1974) confirmed the general belief that hairy lambs have better cold resistance than those with woolly coats. He showed that clipping the birthcoat reduced the cold resistance of the hairy lambs by about 90%. McCutcheon (1981) found that the metabolic rate required to maintain body temperature was significantly related to coat depth. He showed that Drysdale lambs had greater coat depth and a superior resistance to cold stress than Romneys and most of the difference between the two breeds in resistance to cold stress was accounted for by the corresponding differences in coat depth.

1.2.3.2 Birthcoat and adult fleece traits

Variation in the birthcoat is usually associated with differences in the adult fleece. The genetic factors that cause differences in the adult have already begun to show their effects before birth (Ryder and Stephenson, 1968). Working with Welsh Mountain lambs, Wilcox (1968) showed that the birthcoat grade was highly correlated with the kemp grading of five subsequent fleeces. He also indicated that selection of sires and dams on birthcoat types will improve fleece characteristics rapidly.

In lambs with hairy birthcoats, HH and HTCT fibres are usually followed by kemp or very coarse fibres in the adult fleece (Dry, 1935, 1940; Deshpande, 1948; Schinckel, 1951; Ross and Wright, 1954; Stephenson, 1956; Fraser and Short, 1960; Guirgis, 1967; Purser and Karam, 1967; Elgabbas, 1978; Guirgis *et al.*, 1979a, b). A highly significant correlation of 0.70 was found between HH grade and first kemp generation in Barki sheep (Elgabbas, 1978). Selection against HH abundance has proved very effective in reducing kemp in later fleeces (Dry, 1935; Elgabbas, 1978; Guirgis *et al.*, 1979a, b).

Higher birthcoat HH grades tended to be followed in the adult fleece by increased variability of fibre diameter (Schinckel, 1951; Lockart, 1956; Schinckel, 1958; Jacubec and Lindovsky, 1968; Gallagher, 1971; Semmens, 1971) and decreased crimp frequency (Schinckel, 1951) but no relation was found with mean fibre diameter. Lockart (1956) found a positive relationship of birthcoat grade with primary fibres diameter (+0.45) and a negative relationship with secondary fibres diameter (-0.11). He also showed a correlation of 0.83 between birthcoat grade and primary-secondary fibre diameter differences in the adult fleece. Schinckel (1958) postulated that increasing coarseness of the birthcoat was associated with a substantial increase in the variability of fibre diameter and that was due to the increased differences between diameters of fibres produced in primary and secondary follicles together with increasing variability of the primary fibres diameter. Gallagher (1971) reported a correlation coefficient with 15 month mean fibre diameter of 0.42 for birthcoat fibre diameter and -0.19 for birthcoat grade. McCutcheon (1981) found that higher coat depths and mid-side wool weight in the birthcoat were phenotypically associated with higher greasy fleece weight, staple length and slightly poorer colour and a possible increase in fibre diameter and medullation in the hogget fleece.

Coarser birthcoat grades were associated with different body weights in Welsh Mountain lambs; the regression of birth weight, weaning weight and daily gain to 120 days of age were all negative (Wilcox, 1968). Semmens (1971) found that animals with higher birthcoat grades had significantly higher body weights at marking, weaning and hogget stages. Working with Egyptian Barki and Merino X

Barki crosses, Guirgis and Galal (1972) found that kemp score was positively correlated with birth- and weaning-weights and was negatively correlated with fleece weight. Guirgis *et al.* (1982) furthered this investigation by estimating phenotypic and genetic parameters from which they concluded that selection against kemp score would be accompanied by a considerable decrease in birth- and weaning-weights and an increase in yearling weight.

The birthcoat of the lamb's tail has been studied in relation to adult fleece traits. Sugai and Yuhara (1954) showed a positive and high correlation between the wool length of the tail and that of both shoulder and thigh at docking and 12 months of age. They also reported similar results but lower correlations regarding the variation of the wool length. Skarman and Nommera (1955, cited by Wickham, 1982) stated that the birthcoat on the lamb's tail might be useful in selecting for more even and less medullated wool. In Slovakian wool-mutton type Merinos, Planovsky (1960) found no significant correlation between the percentage of kemp at any part of the tail (at 1-8 weeks) and fibre fineness on shoulder, side and back (at 1 year of age). He concluded that if not less than half of the length of the tail has kemp, lambs will, when adult, produce fleeces lacking in uniformity. Bagirov (1968) indicated that with increasing medullated fibres on the tail and of halo-hair fibres on the body at 3 weeks of age, fibre fineness decreased at 1 year as there were direct relationships between these characters. Thus, Bagirov stated that selection at 3 weeks is possible.

The relation between HH coverage grades and arrays is not a very strong one according to Burns (1966), Guirgis (1967) and Burns and Ryder (1974) since Burns (1966) showed that some HH grade VII had valley or plain arrays in Roseworthy Merino samples. Thus, they suggested that high HH birthcoats will not necessarily be followed by a hairy or kempy fleeces. However, in Romney/Drysdale genotypes there is a strong relation between HH grade and fibre type arrays (Wickham, personal communication).

Dry (1935, 1940, 1975) reported that the relation of adult fleece medullation and the fibre type array is complicated, depending not only on the types of fibre present in the array, but also on the degree of hairiness within each type and the extent to which each fibre type sheds. He stated that plateau arrays are probably always followed by some degree of hairiness in the adult fleece and this is associated with extreme within-staple variation in length and coarseness. Deshpande (1948) showed that kemp frequency was related to the type of birthcoat and increased with increasing coarseness and medullation of primary fibres. Burns (1955) postulated that there is no simple and complete relation between birthcoat fibre type arrays and the adult fleece because very different kinds of adult fleece can follow the same fibre type array.

Dry (1935, 1940) suggested that more intense prenatal checks in the array impaired the vigour of the halo-hair follicles sufficiently to prevent secondary kemp growing later in the first year. He stated that coarser fibre type arrays are usually followed by greater hairiness in subsequent fleeces than finer arrays. This trend was confirmed in -type Romney (Ross and Wright, 1954), Kerry, Swaledale and Cheviot crosses (Guirgis, 1967), Uda and Yankassa (Burns, 1967a, b), Barki (Elgabbas, 1978) and Awassi and Hamadani lambs (Guirgis *et al.*, 1979b). Burns (1967b) stated that plain arrays are never followed by kempy fleeces even after a kempy birthcoat. Although Dry (1935) suggested that the prenatal check caused persistent fibre growth, Ryder (1973) indicated that the amount of checking in saddle and even in ravine arrays was insufficient to prevent casting of the adult fleece. For selection against kemp at an early stage, it was recommended for Barki sheep that higher HH grade is essential for the lamb's survival; hence finer fibre type arrays should be considered and a high within-array CT/Pre-CT ratio should be preferable (Elgabbas, 1978). A similar conclusion was drawn by Guirgis *et al.* (1979b) for Awassi and Hamadani sheep.

Burns (1955) found, in Merino X Herdwick crosses, that the coarser arrays were associated with greater within-staple variation in fibre length and diameter in the adult fleece but not with mean fibre length, mean fibre diameter or fleece weight. Guirgis (1979) showed that the relationship of fibre type arrays to the adult fleece was different between breeds. He showed that in Awassi lambs plateau arrays were followed in the adult fleece by longer fibres, higher within-staple variability in fibre length, higher percentages of fine fibres and lower percentages of coarse and kemp fibres while in Hamadani lambs plateau arrays were followed by adult fleeces with finer diameter and slightly lower within-staple variability in fibre length and diameter.

For Barki sheep, Guirgis (1982) concluded that selection of lambs for plateau fibre type arrays would result in higher clean fleece weights, longer staple length and coarser fibre diameter with higher variability than those of saddle array. Within the saddle array, selection of those with lower SK% would result in adult fleeces with higher clean fleece weight and those with reduced CT% would grow adult fleeces with finer diameters.

1.2.3.3 Lamb fleece and later traits

Pohle (1942) studied the relationship between weanling and yearling fleece traits. He indicated that staple length and precentage of clean wool on the weanling may be used for predicting these traits in the yearling fleece. He also reported that fineness and density had some predictive but limited value. Rae (personal communication, cited by Wickham, 1982) obtained an estimate of the phenotypic correlations between lamb and hogget fleece weights of 0.47 and a correlation of 0.49 between quality number in the lamb and hogget fleeces.

1.3 MATERIALS AND METHODS

1.3.1 The Sheep And Their Management

Two Drysdale flocks were involved in the study; one at Massey University (Flock A) and one on a private farm in the central Hawkes Bay region (Flock B).

Lambs were chosen to represent each sire in Flock A (5 sires) and B (9 sires). Within each sire group lambs were classified according to sex and birth rank. Two or three lambs were randomly chosen from each sire within farm, sex and birth rank class. The number of lambs sampled on each occasion at Flock A were: lambing (72), first shearing (61), second shearing (57) and third shearing (55). The corresponding numbers in the B flock were 82, 72, 72 and 35 (ewe hoggets only at the third shearing since ram hoggets were no longer available).

The Drysdales in Flock A grazed an area 2 km south of Palmerston North, about 50 m above sea level with temperatures ranging from 8.8 - 18.4^{o}C and a rainfall ranging from 1000 - 1200 mm/year. Flock B grazed an area in central Hawkes Bay close to the ranges.

The management of both flocks was similar. The breeding season commenced in mid-March each year. Lambing took place during August and early September when lambs were tagged and sexed. The birth rank, date of birth and dam tag number were also recorded. Lambs were weaned in late November or early December and weaning weights were recorded at this time. Some of the ram lambs were culled at weaning as there was not sufficient grazing for all lambs to be kept. First shearing was in mid-December. From mid-December onwards the rams and ewes grazed separately. Second shearing was in April. The ram hoggets were shorn again in September followed by ewe hoggets one month later.

The pastures grazed by both flocks were predominantly perennial ryegrass and white clover. No supplementary feed was provided and no serious drought took place. The stocking rate was about 13/ha in both flocks.

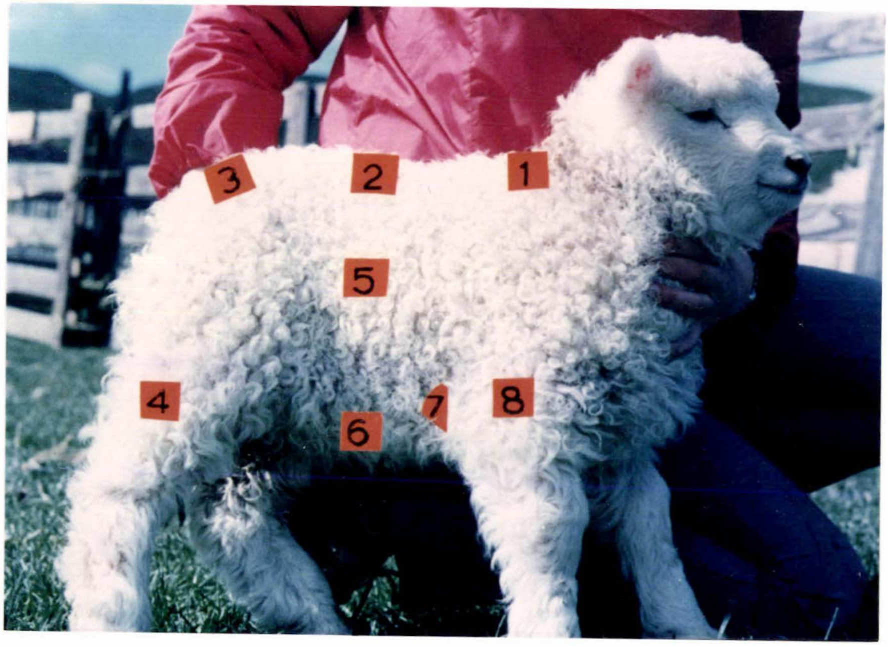

Figure 1. Fixed positions sampled for birthcoat and fleece traits.
1) Withers (WH); 2) Back (BK); 3) Rump (RP);
4) Britch (BR); 5) Mid-side (MS); 6) Belly (BL);
7) Shoulder patch (SP); 8) Shoulder (SH).

1.3.2 Birthcoat Analysis

At about the age of 3-4 weeks, the birthcoat of lambs from both flocks was sampled using fine scissors. In Flock A, samples were taken from 8 body positions: withers, back, rump, shoulder, mid-side, britch, shoulder patch and belly. In Flock B, samples were taken from 4 positions: shoulder, mid-side, britch and back. Sampling positions are shown in Figure 1.

From the main birthcoat sample, a sub-sample of at least 200 fibres was taken and the fibres from whole sub-samples were sorted into the fibre types initially described by Dry (1935) and reviewed by Stephenson (1956) and Dry (1975). The various types of fibres were identified and counted on black velvet. The birthcoat fibres were classified into three main groups on the basis of their tip shape: pre-curly tips, curly-tip and histerotrich fibres. Each group contained fibre types distinguished by their prenatal medullation and their rate of growth. The presence of medulla was confirmed by examination under benzene. Figure 2 shows birthcoat fibre types, and the following is a brief definition of them.

1.3.2.1 The Pre-curly tip group (Pre.CT)

This group is thought to include most of the first fibres to develop in the skin of the foetus. They usually have sickle-shaped tips. This group contains the following fibre types:

A. Halo-hairs (HH): are the longest fibres, strongly medullated throughout with tips which may be straight or sickle. They have a fast growth rate (Side and Rudall, 1964) and hence project above the other birthcoat fibres.

B. Super-sickle fibres (SS): these have a sickle-shaped tip and are shorter than HH fibres. Super-sickles are sub-divided into three types according to the presence or absence of medulla in the prenatal region 'neck' of the fibres:

- i. Super-sickle A (SSA): medullated throughout but usually with smaller medulla diameter and shorter than HH;

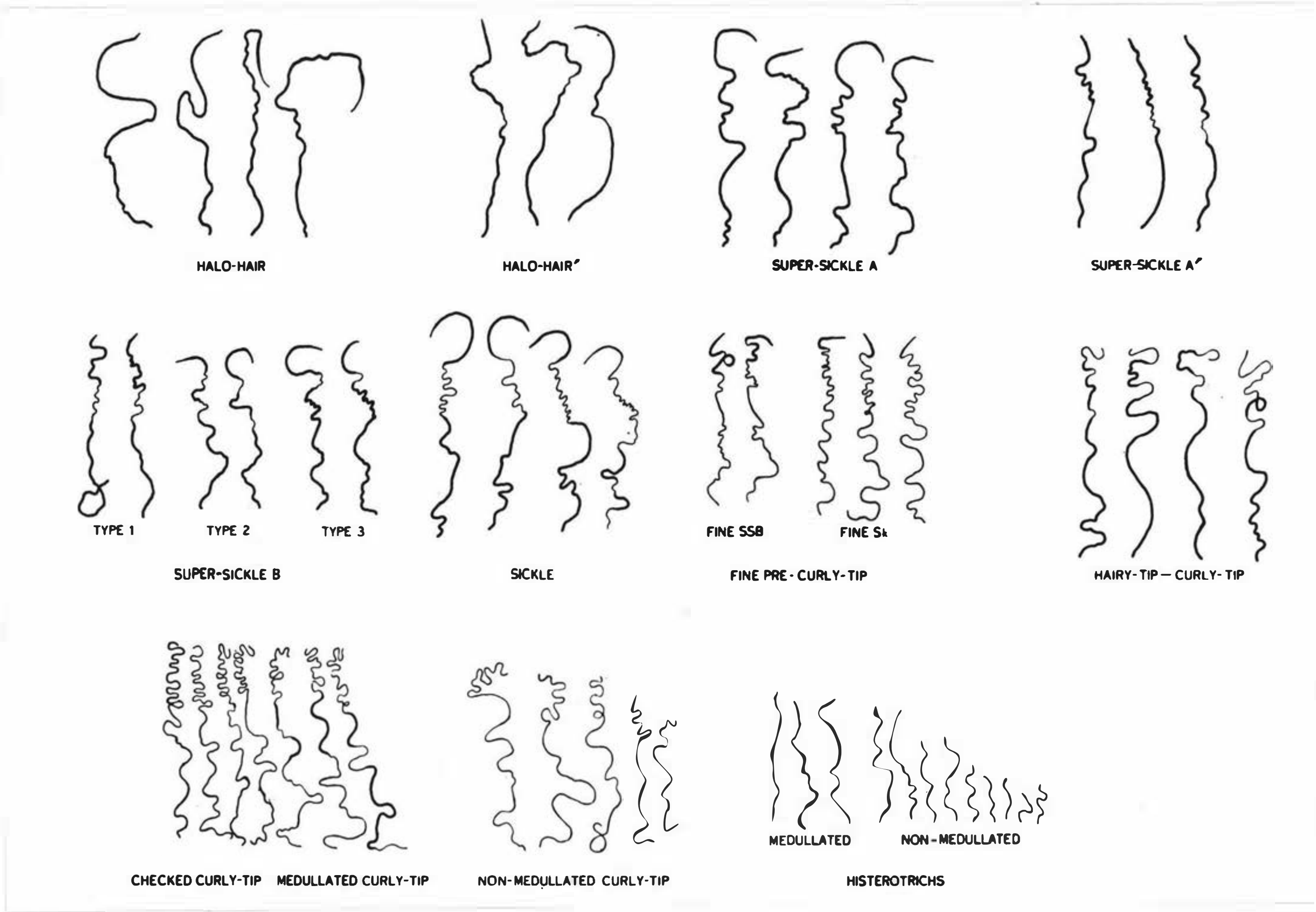

Figure 2. Birthcoat fibre types. Thickening shows medullated part of fibres (after Stephenson, 1956).

ii. Super-sickle A' (SSA'): with medulla only being absent at the birth point;

iii. Super-sickle B (SSB): where medulla is absent from several parts of the neck.

C. Sickle fibres (SK): where the neck below the sickle-shaped tip is free from medulla. SK fibres can be medullated or non-medullated postnatally. The latter are known as fine sickles (F.SK).

1.3.2.2 The Curly-tip group

These fibres characteristically have a curl at the apical end. This group includes:

A. Hairy-tip curly-tips (HTCT): where the prenatal part of the fibre is partly or totally medullated;

B. Curly-tip fibres (CT): which have a prenatal region free of medulla;

C. Checked curly-tip fibres (ChCT): both the prenatal and postnatal parts are free of medulla and these fibres are the most curled of the CT group.

1.3.2.3 The Histerotrich group (Hi)

These are fibres without a definite shape at the apical part which is relatively straight. These fibres are thought to begin growing either just before or after birth. These fibre types are often subdivided into medullated or non-medullated on the basis of the postnatally grown region.

Birthcoat fibres are usually considered as collections or arrays. The fibre type array is described by Dry (1935, 1965) as "a series of fibre types drawn from a small area of the skin, arranged in their believed order of development". Dry (1935) and Stephenson (1956) described different fibre type arrays according to the presence or absence of different fibre types as shown in Table 1.3.1. Saddle

Table 1.3.1 Birthcoat fibre types in different arrays.

Arrays	HH	SSA	SSA'	SSB	SK	F.SK	Ch.CT	HTCT	CT		Hi	
									m#	n.m##	m#	n.m##
Plateau												
* P0	+							+	+	+	+	+
* P1	+	+						+	+	+	+	+
* P2	+	+	+					+	+	+	+	+
* P3	+	+	+	+				+	+	+	+	+
Saddle	+	+	+	+	+			+	+	+	+	+
Ravine	+	+	+	+	+	+		+	+	+	+	+
Valley												
* Truncated	+	+	+	+	+	+	+	+	+	+	+	+
* Beheaded	+	+	+	+			+	+	+	+	+	+
Plain												
* Coarse	+	+	+	+	+	+	+			+		+
* Fine						+	+			+		+

Medullated post-natally
Non-medullated post-natally

array must have at least three sickle fibres (Guirgis, personal communication).

Dry (1935) defined the precipice and transition as features of an array. The precipice was defined as a sharp sudden reduction in coarseness and/or length within the curly-tip group. Transition refers to a gradient in coarseness and/or length within the curly-tip group.

1.3.3 Fleece Analysis

Fleece samples were collected from first, second and third shearings from both flocks. In Flock A, samples were taken from 6 positions (withers, back, rump, shoulder, mid-side and britch) while 4 positions (shoulder, mid-side, britch and back) were sampled from Flock B. Figure 1 shows different sampling positions.

The day before shearing, wool samples were collected close to the skin using Oster electric clippers with size 40 blades. The length of the sides of the rectangles of skin clipped were recorded and the area shorn was calculated (in Flock A, the area shorn was recorded in shoulder and mid-side only in the first shearing while in the second and third shearings the area was recorded in shoulder, mid-side, britch and back, the same positions as in Flock B). Each sample was kept in a plastic bag for further analysis.

Kemp score was subjectively assessed on the greasy sample. The grades were K1 = no kemp, K2 = a few kemp fibres, K3 = moderate kemps, and K4 = dense kemp fibres.

Greasy colour, lustre and handle scores were subjectively graded on the greasy sample. These were graded on a 1 to 9 scale; the higher the score the whiter, the more lustrous, the softer. These grading systems have been discussed by Sumner (1969). The average of two observers' assessments was given to each sample for colour, lustre and handle.

Staple length was the average of five staples taken randomly from each greasy sample. Measurement was made between the base and the tip of the staple. Care was taken not to apply any longitudinal tension to the staple.

The weight of each greasy sample was recorded after conditioning in a humidity room of 20°C and 65% RH for 48 hours and used in the calculation of greasy wool per unit area and clean scoured yield. During scouring each sample was kept in a terylene mesh bag. The scouring equipment consisted of 4 bowls (36 L each). Squeeze rollers removed excess liquor when samples were transferred from bowl to bowl. Conditions of each bowl are detailed in Table 1.3.2. After the final bowl, the wool was spun dry and dried further in a forced draught at 82°C before returning to the conditioning room. After 48 hours, the clean scoured weight was recorded and clean scoured yield was calculated as

$$\frac{\text{weight of scoured sample}}{\text{weight of greasy sample}} \times 100.$$

Clean wool per unit area was also recorded.

In a separate study using this scouring method, the residual ether extract (ASTM, 1958) was found to be 1.59%.

Each clean scoured sample was subjectively graded for scoured colour. The same scale from 1 to 9 mentioned earlier with greasy colour was used. Then each sample was hand-carded. After conditioning in the humidity room at 20°C and 65% RH for 48 hours, samples were weighed and tested in that atmosphere for bulk, resilience, tristimulus colour values and medullation index.

Bulk and resilience were measured on a 10 gms clean scoured and carded sample using a WRONZ bulkometer (Bedford *et al.*, 1977).

Using a Hunterlab D25 D2M Colorimeter, red (X), green (Y) and blue (Z) reflectances were measured on two 3 gms sub-samples taken from each clean and carded sample. As samples were not degreased after scouring, the residual grease might impair the whiteness of these samples. Each sub-sample was measured on two faces and the average of the four readings was recorded for each value. Y-Z was also calculated. Higher Y-Z values indicate yellow discolouration.

Table 1.3.2 Conditions of each bowl in the scouring method

Bowl	Temp. ^{o}C	Det.# (ml)	Na_2CO_3 (gm)	$NaHCO_3$ (gm)	pH
1	55	8	51	-	9.5
2	51	23	-	227	8.2
3	46	19	-	-	8.1
4	Cold	Rinse	-	-	7.6

Det. = Detergent (a technical grade of nonyl phenol condensed with ethylene oxide).

Medullation index was determined using a WRONZ medullameter (Lappage and Bedford, 1983). This operates on a similar principle to that described by McMahon (1937). The main difference is that the immersion medium was Mobil Certrex 47 instead of benzene. The medullameter was calibrated against measurements made by projection microscope so that the medullameter index corresponds closely to the percentage area of medulla measured by projection microscope. The measurements were made on a 0.5 gms sub-sample taken from each clean scoured, carded and conditioned sample.

In Flock A, greasy fleece weight was recorded at the first and third shearings. Clean fleece weights were calculated from the greasy fleece weights and the mean yield of the six positions sampled.

1.3.4 Statistical Procedures

1.3.4.1 Analysis of variance studies

For all traits studied ordinary least squares analysis was carried out to estimate parameters and to partition the variability into its sources. For this purpose, the REG statistical package available at the Massey University Computer Centre was used (Gilmour, 1981). Percentages of birthcoat fibre types were transformed to arcsine values.

Preliminary analyses of the data indicated that the fixed effects of position, birth rank, sex, age of dam, flock, shearing and the covariance on date of birth were important sources of variation. Sire effects were included in all models and were assumed to be randomly drawn from a population with zero mean and variance $\sigma^2 s$. Some of the first order interactions showed significant effects; therefore they were included where necessary in the models. Non-significant interactions, in particular those of sire X position as well as position X sex interactions, were omitted from the models. Second order interactions of particular interest were also tested, but none was found to be significant; hence they were also omitted from all models.

As mentioned earlier for greasy and clean wool per unit area, four positions (shoulder, mid-side, britch and back) were measured in Flock B, while two positions only were measured in Flock A at the first shearing (shoulder and mid-side) and the same four positions as in Flock B were measured in the second and third shearings. Therefore, while the models for greasy and clean wool per unit area were the same as the other traits in Flock B, they differed in Flock A mainly due to number of positions involved in the analysis.

Four linear models were used in order to represent different aspects of the data. The effects included in the models and the degrees of freedom are shown in Table 1.3.3. Some symbols were used to represent a particular model; A and B refer to flocks A and B respectively, and the numbers 1, 2 or 3 denote shearings involved in that model, i.e. first, second or third shearing respectively. The four models used in the data were:

A. *Combining shearing data*: the sheep included in these models had records for all three shearings in Flock A (55 sheep) and for the first and second shearings in Flock B (72 sheep).

A123 is a model in which data for Flock A for the three shearings were combined (for both greasy and clean wool per unit area, shoulder and mid-side samples only included in that model while all the six positions were involved in the analysis of the other traits). In models A12 and B12 the first two shearings for both flocks (A and B) were combined. A23 is a special model for both greasy and clean wool per unit area in which the last two shearings were combined to analyse the four positions involved.

The third shearing in Flock B was excluded from the analysis since the ram data were not available. Position, sex, birth rank, age of dam and shearing were fixed effects while the sire effect was considered to be random. The interactions fitted can be seen in Table 1.3.3.

B. *Combining flock data*. A model combining both flocks in the first (AB1) and second shearing (AB2) was also used. The withers and rump positions were excluded from Flock A to match with the same four positions (shoulder, mid-side, britch and back) as in Flock B. For both greasy and clean wool per unit area only shoulder and mid-side samples were included in AB1 while the same four positions were involved in AB2. Factors fitted can be seen in Table 1.3.3.

Table 1.3.3 Degrees of freedom of factors included in different models analysing fleece traits

	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Total	989	659	575	571	515	365	327	341	287	329	139
Position (POS)	5	5	3	3	3	5	3	5	3	5	3
Sex (S)	1	1	1	1	1	1	1	1	1	1	♀♀ only
Birth rank (BR)	1	1	1	1	1	1	1	1	1	1	1
Dam age	1	1	1	1	1	1	1	1	1	1	1
Birth date	1	1	1	1	1	1	1	1	1	1	1
Shearing (SHG)	2	1	1								
Sire	4	4	8			4	8	4	8	4	8
SHG X POS	10	5	3								
SHG X Sire	8	4	8								
SHG X S	2	1	1								
SHG X BR	2	1	1								
Sire X S	4	4	8			4	8	4	8	4	
Sire X BR	4	4	8			4	8	4	8	4	8
BR X S	1	1	1			1	1	1	1	1	
Flock				1	1						
Sire / Flock				12	12						
Flock X S				1	1						
Residual	943	625	529	550	494	343	295	319	255	307	117

C. Separate flock and shearing data. A model provides separate analyses for both flocks (A, B) in the first (A1, B1), second (A2, B2) and third shearing (A3). The six positions in Flock A and the four positions in Flock B were involved in the analyses of all traits except for greasy and clean wool per unit area in Flock A in which only shoulder and mid-side positions were included in A1, while the four positions (shoulder, mid-side, britch and back) were involved in A2 and A3.

D. Separate flock, shearing and sex data. A series of analyses of this type was carried out but only the results for Flock B in the third shearing are presented since ram data were not available for that flock and shearing.

To obtain the expected value of the mean squares, Searle (1970) treated both fixed and mixed models as completely random except that the σ^2 terms corresponding to fixed effects and interactions of fixed effects are changed into quadratic functions of these fixed effects. K coefficients were calculated (Snedecor and Cochran, 1980). Variance components were estimated by equating the calculated mean squares to their expected values.

1.3.4.2 Multiple regression studies

Multiple regression analyses were carried out within the flock-sex groups using the REG statistical package (Gilmour, 1981). The multiple regression equation had the following form:

$$Y = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n + e$$

where Y = the average of third shearing for a particular trait; medullation index, bulk, greasy and clean third fleece weights,

a = constant

$x_1, x_2, \ldots, x_n$ refer to independent variates expressed as deviations from their respective means. In this case all birthcoat and first shearing traits were included in the analysis as independent variables,

$b_1, b_2, \ldots, b_n$ denote the partial regression coefficients of Y on variable x_i,

e = error term assumed to be normally and independently distributed with a mean of zero and constant variance.

In discussing the choice of independent variates to be included in a regression analysis, Hocking (1976) indicated that the best technique (if it is computationally feasible) is to analyse all possible combinations of the independent variates in order to select the optimal subset. The REG statistical package provides screening for all possible combinations among independent variates. The option of having a minimum of two and a maximum of four variates was invoked in all models.

The best models were selected on the basis of the adjusted R^2 (squared multiple correlation coefficient).

$$\text{Adjusted } R^2 = 1 - \frac{(1 - R^2)\ (\text{Total degrees of freedom})}{(\text{Error degrees of freedom})}$$

The regression with the highest adjusted R^2 is also the one with the lowest residual mean squares. The individual factors in the model are not necessarily significant.

1.3.4.3 Correlations studies

Correlation coefficients between various traits were calculated within flock-sex groups. Where no significant differences between correlations were found, they were pooled across sexes and then across flocks using Fisher's Z transformation (Snedecor and Cochran, 1980).

1.4 RESULTS AND DISCUSSION

1.4.1 Factors Affecting Fleece Traits

1.4.1.1 Kemp score

Position was generally the main source of variation in kemp score. Tables 1.4.1 - 1.4.8 show that kemp score, harshness and medullation indices increased towards the posterior parts of the body. Dorsal positions had higher kemp score and harsher handle but lower medullation indices compared with lateral positions. At later shearings, kemp score increased on the back position but decreased on mid-side, britch and withers positions. The shearing X position interaction appeared to be significant in Flock A.

Guirgis (1980) showed that kemp score was lower in the anterior parts of the body in Barki sheep. Coarser wool on the posterior positions was also reported in New Zealand Romney (Goot, 1945) and in Indian breeds (cited by Sumner and Revfeim, 1973).

In a separate study, ten N^dN^d ewes running in Flock A were used to study fibre type ratio. At 3 weeks of age, staples on the shoulder, mid-side, britch and back positions were tied together to retain shed fibres (Guirgis, 1967). The day before shearing these staples were collected using fine scissors. The whole staple (average of 1097 fibres) was split into kemp, medullated and non-medullated fibres. The same technique was applied 3 weeks after the second and third shearings.

Highly significant shearing X sheep and shearing X position interactions occurred with contributions of 17.5% and 21.6% to the total variance in percentage of kemp fibres respectively. It appeared that rankings of sheep and positions varied across the three shearings. The sheep X position interaction was also significant and contributed 9.7% of the total variance in percentage of kemp fibres.

Flock A samples had higher kemp score in the first shearing but the size of the flock effect was small according to Table 1.4.9. The sire variance component was larger in Flock A and almost negligible in Flock B. The proportion of among-sire variation increased at later

Table 1.4.1 Least squares means and effects for first fleece traits in Flock A (*A1*)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	2.83	3.13	31.37	4.11	4.69	63.32	65.06	61.61	3.45	15.55	76.68	25.54	19.01	3.73	21.69	7.44
Sex																
Male	+0.08	+0.03	+0.49	-0.01	-0.12	-0.21	-0.22	-0.26	+0.04	-0.18	+0.11	-0.80	-0.47	+0.01	+0.03	-0.01
Birth rank																
single	+0.03	-0.14	-0.76	-0.02	+0.20	+0.37	+0.44	+0.43	+0.01	+0.40	-1.08	+1.25	+0.86	0.00	+0.16	+0.07
Dam age																
2-yr	-0.02	-0.02	+0.15	-0.05	-0.19	-0.70	-0.83	-0.72	-0.11	-0.44	+0.33	-1.41	-1.09	-0.07	+0.14	+0.12
Position																
SH	-0.82	+0.60	+0.15	+0.52	+1.04	+1.54	+1.74	+2.20	-0.46	-0.35	-2.00	-0.07	-0.17	+0.11	-0.13	+0.12
MS	-0.25	+0.21	+3.04	+0.75	+1.55	+2.96	+3.09	+4.67	-1.58	+0.34	-0.84	+0.07	+0.17	+0.18	+0.38	+0.17
BR	+0.41	-0.43	+5.08	+0.24	+0.52	+1.58	+1.66	+2.23	-0.57	-0.90	-4.30	na	na	-0.13	+1.77	+0.44
WH	-0.33	+0.09	-5.07	-0.38	-0.76	-1.88	-1.98	-3.02	+1.04	+1.19	+3.02	na	na	+0.05	-1.36	-0.37
BK	+0.31	-0.22	-3.25	-0.66	-1.27	-2.78	-2.97	-4.29	+1.33	+0.33	+2.76	na	na	-0.25	-0.30	+0.01
RP	+0.69	-0.25	+0.05	-0.48	-1.07	-1.41	-1.54	-1.78	+0.24	-0.60	+1.36	na	na	+0.03	-0.36	-0.36
Birth date	0.00	+0.01	-0.04	+0.01	+0.02	+0.02	+0.02	+0.03	-0.01	-0.12	+0.10	-0.18	-0.11	0.00	-0.01	0.00

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects

na = not available

Table 1.4.2 Least squares means and effects for second fleece traits in Flock A (*A2*)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	2.63	3.76	25.25	4.93	4.31	62.10	64.29	60.12	4.17	10.87	80.09	29.90	24.82	3.90	22.03	7.66
Sex																
Male	-0.01	-0.05	+0.38	-0.04	-0.06	-0.21	-0.19	-0.12	-0.07	-0.23	+0.36	-3.04	-2.35	-0.08	+0.21	+0.01
Birth rank																
single	+0.04	-0.03	-0.72	-0.06	-0.01	-0.26	-0.22	-0.23	+0.01	-0.05	-1.13	+0.23	-0.14	0.00	+0.30	+0.15
Dam age																
2-yr	+0.06	+0.01	+0.25	-0.06	-0.07	-0.34	-0.34	-0.45	+0.11	-0.34	+0.13	-0.84	-0.68	-0.06	+0.10	-0.03
Position																
SH	-1.05	+0.48	-1.26	+0.18	+0.90	+1.43	+1.37	+1.79	-0.43	+0.32	-2.11	-5.22	-5.73	+0.26	-0.75	-0.15
MS	-0.40	+0.13	+3.32	+0.25	+1.18	+2.88	+2.91	+4.22	-1.31	+0.69	-1.97	-6.37	-6.65	+0.03	-0.07	-0.16
BR	+0.37	-0.50	+5.29	-0.61	+0.38	+1.86	+1.79	+2.17	-0.38	-0.40	-3.34	-5.26	-5.94	-0.20	+1.55	+0.15
WH	-0.56	+0.32	-4.55	+0.40	-0.61	-1.66	-1.63	-2.62	+0.99	+0.58	+5.52	na	na	+0.19	-1.48	-0.25
BK	+0.68	-0.10	-2.78	+0.04	-1.04	-2.47	-2.33	-3.21	+0.88	-0.29	+3.01	+16.84	+18.32	-0.11	+0.43	+0.21
RP	+0.96	-0.33	-0.02	-0.25	-0.82	-2.04	-2.11	-2.36	+0.24	-0.89	-1.10	na	na	-0.16	+0.32	+0.20
Birth date	+0.01	+0.01	+0.03	0.00	+0.01	+0.02	+0.01	+0.02	-0.02	-0.02	+0.05	-0.04	-0.01	+0.01	-0.03	-0.02

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects

na = not available

Table 1.4.3 Least squares means and effects for third fleece traits in Flock A (A3)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	2.18	3.29	31.18	3.65	4.97	62.81	64.71	60.51	4.20	14.96	79.43	35.75	30.07	3.42	22.28	7.95
Sex																
Male	-0.07	-0.05	+1.05	-0.01	-0.05	-0.01	-0.02	+0.17	-0.19	+0.49	+1.34	+0.11	+0.67	+0.05	-0.02	-0.07
Birth rank																
single	-0.02	-0.03	-0.83	-0.02	+0.05	-0.17	-0.16	-0.19	+0.02	-0.37	-0.88	-0.41	-0.63	+0.02	+0.28	+0.17
Dam age																
2-yr	-0.15	-0.08	+1.26	-0.04	+0.03	+0.04	+0.03	+0.02	+0.01	+0.68	+0.25	-0.01	-0.04	-0.13	-0.07	-0.09
Position																
SH	-0.86	+0.32	+0.14	-0.22	-0.10	-0.34	-0.34	-0.83	+0.50	+1.63	-1.87	+0.37	-1.97	+0.28	-1.56	-0.59
MS	-0.46	+0.28	+5.75	-0.32	+1.30	+3.21	+3.36	+4.46	-1.10	+0.73	-5.63	-7.62	-9.33	+0.22	+1.87	+0.43
BR	+0.36	-0.46	+3.33	-0.39	+0.21	+0.47	+0.47	+0.99	-0.52	+0.05	-2.90	+0.41	-2.34	-0.14	-0.16	-0.33
WH	-0.90	+0.32	-7.09	+0.61	-0.43	-1.23	-1.27	-1.75	+0.48	+0.47	+5.96	na	na	+0.19	-1.02	-0.05
BK	+0.99	-0.13	-2.34	+0.28	-0.65	-1.18	-1.22	-2.00	+0.78	-1.69	+4.35	+6.84	+13.65	-0.30	+1.00	+0.58
RP	+0.87	-0.33	+0.22	+0.03	-0.32	-0.92	-1.01	-0.86	-0.15	-1.19	+0.10	na	na	-0.25	-0.14	-0.05
Birth date	+0.01	0.00	-0.11	0.00	+0.01	-0.02	-0.02	-0.02	-0.01	0.00	+0.03	+0.03	+0.03	+0.01	-0.03	-0.01

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects

na = not available

Table 1.4.4 Least squares means and effects for first fleece traits in Flock B (*B1*)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	3.15	4.25	15.47	5.58	3.64	57.95	59.17	53.03	6.14	14.72	85.64	25.24	21.93	3.61	18.52	6.96
Sex																
Male	+0.01	-0.11	-1.15	-0.10	-0.08	-0.35	-0.37	-0.71	+0.34	-0.03	-0.09	-0.90	-0.71	+0.03	0.00	+0.06
Birth rank																
single	+0.09	-0.10	+0.82	+0.09	-0.02	+0.07	+0.07	-0.08	+0.16	+0.37	+0.11	+1.37	+1.11	0.00	+0.12	-0.06
Dam age																
2-yr	+0.01	-0.18	+0.63	-0.25	-0.21	+1.01	+1.09	+0.68	+0.41	-0.13	-0.80	-1.15	-0.89	-0.07	+0.44	+0.24
Position																
SH	-0.80	+0.72	-1.43	+0.41	+0.36	+1.39	+1.49	+1.27	+0.22	+0.65	+0.06	+0.15	-0.01	+0.27	-1.28	-0.39
MS	-0.42	+0.52	+0.79	+0.48	+1.10	+2.86	+3.05	+3.69	-0.64	+0.09	-0.63	-4.65	-3.99	+0.27	-0.35	-0.19
BR	+0.36	-0.46	+3.40	-0.01	+0.15	+1.09	+1.12	+1.13	-0.01	-0.33	-2.57	-0.32	-0.96	-0.16	+1.48	+0.41
BK	+0.87	-0.78	-2.75	-0.88	-1.62	-5.33	-5.66	-6.09	+0.44	-0.41	+3.15	+4.83	+4.95	-0.39	+0.16	+0.17
Birth date	-0.01	-0.01	+0.31	-0.03	+0.03	+0.14	+0.16	+0.19	-0.03	-0.03	-0.14	-0.01	-0.05	0.00	+0.07	0.00

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects

Table 1.4.5 Least squares means and effects for second fleece traits in Flock B (*B2*)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	2.90	4.02	21.48	4.42	5.20	63.14	64.48	62.10	2.37	16.50	80.08	34.13	27.49	4.48	21.72	7.90
Sex																
Male	-0.06	-0.06	-0.02	-0.34	-0.34	-0.83	-0.87	-1.26	+0.39	-0.11	-0.55	-1.43	-1.36	-0.01	+0.27	+0.11
Birth rank																
single	+0.03	-0.04	-0.10	+0.04	-0.08	+0.10	+0.10	+0.12	-0.02	-0.25	+0.35	-0.04	+0.03	-0.02	+0.05	-0.02
Dam age																
2-yr	+0.05	-0.14	+3.26	+0.03	+0.23	+0.61	+0.55	+1.01	-0.46	+0.70	-0.11	+1.33	+0.97	-0.17	+0.62	+0.13
Position																
SH	-0.93	+0.61	-2.81	+0.25	+0.57	+0.74	+0.81	+0.48	+0.33	+0.15	-1.24	-3.67	-3.43	+0.45	-0.94	-0.25
MS	-0.39	+0.26	+1.13	+0.21	+0.55	+1.40	+1.37	+2.13	-0.76	+1.35	-1.06	-1.43	-1.55	+0.14	-0.40	-0.15
BR	+0.32	-0.53	+4.56	-0.64	+0.20	+1.03	+1.06	+1.36	-0.30	-0.83	-1.47	+3.55	+2.50	-0.30	+0.69	+0.06
BK	+1.01	-0.35	-2.89	+0.18	-1.32	-3.18	-3.23	-3.96	+0.73	-0.67	+3.76	+1.54	+2.47	-0.30	+0.66	+0.33
Birth date	0.00	-0.01	+0.09	0.00	-0.01	-0.03	-0.02	-0.07	+0.05	-0.04	+0.10	-0.03	+0.01	-0.02	-0.03	-0.01

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects

Table 1.4.6 Least squares means and effects for third fleece traits in Flock B ewes (*B3*)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	3.11	3.71	12.84	3.49	6.62	61.39	63.32	61.10	2.22	13.73	75.01	30.64	22.74	3.75	21.47	7.89
Sex																
Male	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Birth rank																
single	+0.03	-0.02	+0.83	+0.05	+0.09	+0.13	+0.13	-0.05	+0.19	-0.29	+0.02	+0.56	+0.47	-0.05	+0.18	+0.04
Dam age																
2-yr	+0.18	-0.14	-1.77	-0.12	+0.46	+0.38	+0.43	+0.89	-0.45	+0.49	+0.49	-0.13	-0.07	-0.07	+1.03	+0.37
Position																
SH	-0.69	+0.43	-0.80	+0.41	+1.26	+0.70	+0.70	+1.76	-1.06	+0.36	-0.44	+0.24	-0.09	+0.41	-0.99	-0.27
MS	-0.14	+0.06	0.00	+0.29	+0.92	+1.51	+1.59	+2.51	-0.93	+1.50	-0.91	+0.12	-0.34	+0.12	-0.40	-0.25
BR	+0.29	-0.20	+3.50	-0.31	+0.41	+1.55	+1.59	+2.13	-0.55	-1.20	-5.47	-4.98	-5.56	-0.02	+1.02	+0.29
BK	+0.54	-0.29	-2.70	-0.39	-2.59	-3.76	-3.88	-6.41	+2.53	-0.66	+6.82	+4.63	+5.98	-0.51	+0.38	+0.23
Birth date	0.00	-0.01	+0.32	0.00	-0.01	+0.02	+0.02	-0.03	+0.05	+0.03	+0.13	+0.07	+0.10	0.00	-0.03	-0.01

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects

na = not available

Table 1.4.7 Least squares means and effects for first fleece traits in both flocks (*AB1*)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	2.96	3.62	29.58	4.71	4.13	61.39	63.10	57.97	5.13	15.85	78.92	26.11	20.39	3.58	22.09	7.69
Flock																
A	+0.07	-0.20	+12.33	+0.12	-0.19	+1.13	+1.07	+1.21	-0.14	+0.08	+2.29	+0.97	+0.84	+0.10	+2.72	+0.70
Sex																
Male	+0.05	-0.04	-0.28	-0.07	-0.09	-0.28	-0.28	-0.43	+0.15	-0.06	+0.19	-0.58	-0.47	+0.02	0.00	+0.01
Birth rank																
single	+0.07	-0.11	+0.05	+0.03	+0.06	+0.25	+0.28	+0.15	+0.13	+0.41	-0.34	+1.24	+0.89	0.00	+0.15	0.00
Dam age																
2-yr	0.00	-0.06	+0.58	-0.06	-0.12	-0.14	-0.16	-0.17	+0.01	-0.23	+0.01	-0.99	-0.79	-0.05	+0.20	+0.16
Position																
SH	-0.77	+0.65	-1.29	+0.37	+0.45	+1.10	+1.22	+1.15	+0.07	+0.29	-0.35	+1.35	+1.07	+0.21	-0.97	-0.25
MS	-0.31	+0.37	+1.21	+0.50	+1.10	+2.55	+2.69	+3.60	-0.91	+0.26	-0.26	-1.35	-1.07	+0.24	-0.22	-0.11
BR	+0.42	-0.47	+3.58	+0.01	+0.11	+0.95	+0.98	+1.09	-0.11	-0.51	-2.84	na	na	-0.14	+1.42	+0.34
BK	+0.67	-0.56	-3.50	-0.88	-1.66	-4.59	-4.89	-5.84	+0.95	-0.03	+3.45	na	na	-0.32	-0.22	+0.03
Birth date	0.00	+0.01	+0.01	0.00	+0.03	+0.05	+0.05	+0.08	-0.03	-0.10	+0.08	-0.14	-0.09	0.00	-0.02	-0.01

The Flock B, female, twin and older dam effects have the same magnitude as, but opposite sign to, the Flock A, male, single and 2-yr dam effects

na = not available

Table 1.4.8 Least squares means and effects for second fleece traits in both flocks (*AB2*)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
Mean	2.72	3.66	24.28	4.55	4.62	62.78	64.79	60.81	3.98	13.90	79.36	31.03	24.79	3.99	22.38	7.97
Flock																
A	+0.03	-0.08	+5.13	+0.20	-0.03	+0.56	+0.62	+0.45	+0.17	-0.73	-1.88	-1.86	-2.22	+0.09	+1.71	+0.14
Sex																
Male	-0.03	-0.04	-0.13	-0.22	-0.24	-0.62	-0.61	-0.81	+0.20	-0.21	+0.01	-2.23	-1.83	-0.06	+0.20	+0.05
Birth rank																
single	+0.03	-0.05	-0.28	0.00	-0.03	+0.01	+0.04	+0.06	-0.02	-0.15	-0.38	+0.08	-0.04	-0.02	+0.19	+0.07
Dam age																
2-yr	+0.05	-0.02	+0.31	-0.01	-0.07	-0.11	-0.15	-0.14	-0.01	+0.03	+0.59	+0.42	+0.44	-0.10	+0.07	0.00
Position																
SH	-0.94	+0.55	-2.63	+0.23	+0.56	+0.64	+0.64	+0.51	+0.13	+0.19	-1.13	-2.49	-2.42	+0.37	-0.98	-0.21
MS	-0.35	+0.20	+1.59	+0.24	+0.67	+1.65	+1.64	+2.50	-0.87	+1.02	-0.98	-1.75	-1.78	+0.09	-0.39	-0.16
BR	+0.38	-0.52	+4.38	-0.61	+0.12	+0.99	+0.97	+1.17	-0.20	-0.68	-1.81	+1.52	+0.79	-0.25	+0.94	+0.10
BK	+0.91	-0.24	-3.34	+0.13	-1.36	-3.27	-3.25	-4.18	+0.94	-0.54	+3.92	+2.72	+3.41	-0.21	+0.43	+0.27
Birth date	0.00	+0.01	+0.04	0.00	+0.01	-0.01	-0.01	-0.01	-0.01	-0.02	+0.08	-0.06	-0.02	0.00	-0.04	-0.02

The Flock B, female, twin and older dam effects have the same magnitude as, but opposite sign to, the Flock A, male, single and 2-yr dam effects

Table 1.4.9 Percentages of total variance due to different factors (with significance): *Kemp Score*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	50.1**	48.8**	70.2**	66.7**	65.1**	52.6**	71.9**	52.9**	69.2**	55.5**	35.8**
Sex (S)	0.0	0.0	0.1	0.1	0.1	1.4	0.0	0.4	0.7	0.9	♀♀ only
Birth rank (BR)	0.0	0.0	0.6	0.8**	0.0	0.0	1.2	0.0	0.1	0.2	0.0
Dam age	0.0	1.1**	0.4	0.3	0.2	0.0	1.5**	2.3**	0.0	0.6	2.7
Birth date											
Shearing (SHG)	0.0	0.0	1.0								
Sire	4.6	3.2	0.4			0.7	0.0	8.1	0.8	8.6	0.0
SHG x POS	4.3**	3.5**	0.3								
SHG x Sire	2.1**	2.9**	0.0								
SHG x S	1.2**	1.5**	0.1								
SHG x BR	0.0	0.0	0.1								
Sire x S	0.0	0.0	0.9*			0.3	2.1**	0.0	0.0	0.2	
Sire x BR	1.2**	1.2*	1.0*			1.2	2.4**	1.1	1.5	0.8	10.7*
BR x S	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	
Flock				1.6	0.0						
Sire/flock				0.5	3.4**						
Flock x S				0.2	0.1						
Residual	36.5	37.9	24.9	29.8	31.1	43.8	21.0	35.2	27.8	33.3	50.9
Res. mean sq.	0.37	0.34	0.30	0.26	0.42	0.26	0.22	0.41	0.38	0.43	0.52

* $p<0.05$, ** $p<0.01$

shearings, perhaps due to a decrease in some environmental effects. The ranking of sires changed among shearings as the shearing X sire interaction was significant in Flock A.

Sex differences contributed little to the total variance in kemp score. Shearing X sex interaction was significant in Flock A as rams tended to have lower kemp score in later fleeces. There was one month's difference in the time of the third shearing between rams and ewes in Flock A, and this may be a factor in the interaction. Both sexes were also subjected to different environments after the first shearing.

Birth rank had little effect on kemp score. Sire rankings were not consistent for single and twin offsprings, therefore sire X birth rank interaction was often significant. The offspring of younger dams had generally higher kemp score in Flock B, but showed no trend in Flock A. The size of the effect was very small.

1.4.1.2 Handle grade

Table 1.4.10 indicates that position was the main source of variation controlling handle. Harshness tended to increase towards the posterior parts of the body. Dorsal positions were also harsher than the lateral ones. Shearing X position interaction was significant in both flocks as the ranking of positions was inconsistent among shearings. There were considerable shearing differences in handle in Flock A. Second shearing samples had the softest wool compared with the first and third shearings, possibly due to the lowest medullation index in the second shearing (Table 1.4.2). The second fleece, after four-month growth, was approximately the time when kemp-producing follicles were inactive and preparing for the second kemp generation.

Flock A samples were harsher than those of Flock B. Between-flock variations were larger in the first shearing (AB1). The sire within flock variations were significant in the first and second shearings (AB1, AB2). Generally, the size of the effect was small and not consistent in direction.

Table 1.4.10 Percentages of total variance due to different factors (with significance): *Handle Grade*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	23.9**	21.8**	44.3*	34.8**	48.2**	22.6**	50.3**	34.1**	52.3**	30.7**	33.3**
Sex (S)	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.5	0.2	0.3	♀♀ only
Birth rank (BR)	1.3	1.2	0.0	1.9**	0.9*	6.7	0.6	0.0	0.0	0.7	0.0
Dam age	0.8**	0.9*	1.3*	2.8**	0.0	0.0	1.3	0.0	0.3	0.2	3.9*
Birth date	**	**		*		**		*			
Shearing (SHG)	13.8	18.3	0.0								
Sire	1.5	1.4	2.2			5.6	1.1	0.7	6.4	4.2	0.0
SHG x POS	1.1*	0.8	3.8**								
SHG x Sire	0.8*	0.3	2.5**								
SHG x S	0.1	0.3	0.2								
SHG x BR	1.4**	2.0**	0.4								
Sire x S	1.0*	1.2*	2.4**			0.0	3.8**	1.5	0.1	0.3	
Sire x BR	0.3	0.8	0.5			0.0	1.1	2.3*	2.1	0.0	16.5**
BR x S	0.0	0.0	3.5**			0.0	2.2*	0.0	0.5	0.0	
Flock				16.7	0.0						
Sire/flock				2.7**	4.8**						
Flock x S				1.3*	0.0						
Residual	53.9	51.3	38.9	39.9	45.7	64.9	39.7	61.0	38.2	63.5	46.0
Res. mean sq.	0.29	0.32	0.40	0.55	0.28	0.39	0.56	0.25	0.27	0.25	0.18

* $p<0.05$, ** $p<0.01$

Table 1.4.11 Percentages of total variance due to different factors (with significance): *Medullation Index*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	27.7**	26.4**	26.0**	10.1**	25.8**	29.5**	8.6**	29.8**	27.9**	29.9**	19.3**
Sex (S)	0.3	0.2	0.0	0.0	0.0	0.0	1.5	0.3	0.0	1.8	♀♀ only
Birth rank (BR)	2.3	3.1	0.0	0.0	0.1	1.5	0.0	1.6	0.0	0.7	0.0
Dam age	0.5*	0.2	0.0	2.6**	0.9*	1.0*	0.0	0.0	0.0	0.9	2.8
Birth date			**				*		**		**
Shearing (SHG)	8.9	19.0	13.3								
Sire	5.8	4.6	9.7			15.1	7.9	0.0	18.1	7.9	11.4
SHG x POS	1.0*	0.0	0.1								
SHG x Sire	2.5**	4.1**	2.9**								
SHG x S	0.4	0.0	0.0								
SHG x BR	0.0	0.0	0.6								
Sire x S	0.0	0.0	1.2			3.9	0.0	0.0	2.5	0.0	
Sire x BR	1.5**	1.8**	4.9**			1.2**	5.7*	8.7**	6.0**	1.5	15.2**
BR x S	0.0	0.0	0.9*			0.0	0.9	0.0	2.4*	0.1	
Flock				32.0	21.0						
Sire/flock				7.4**	11.4**						
Flock x S				1.2*	0.1						
Residual	49.2	40.7	40.5	46.8	40.7	47.8	75.4	59.6	43.1	57.2	51.1
Res. mean sq.	27.08	21.92	22.26	55.86	27.44	22.53	74.46	26.66	25.60	36.88	21.60

* $p<0.05$, ** $p<0.01$

Sex had no effect on handle in both flocks. Singles were generally harsher than twins, this birth rank effect being higher in the first shearing. The ranking of singles and twins changed across shearings as the shearing X birth rank interaction was significant in Flock A.

The offspring of younger dams had generally harsher wool than those of older dams. The effect of age of dam contributed little to the total variance in handle. Earlier-born lambs had harsher wool than those born later. That trend was significant in Flock A.

1.4.1.3 Medullation index

Position was the main source of variation in medullation index (Table 1.4.11). There was a general trend for the medullation index to be higher in the lateral positions and towards the posterior parts of the body. The effect of shearing was remarkable in both flocks; however, no clear trend was indicated.

The between-flock difference was also an important factor in the medullation index. Flock A samples had much higher medullation indices (29.3) than those of Flock B (16.6). The among-sire variations were often high in both flocks. The ranking of sires changed among shearings and between birth ranks as the interactions of sire with both shearing and birth rank were often significant.

Rams generally had a higher medullation index in Flock A. That trend was reversed in Flock B. Sex, birth rank and age of dam effects contributed little to the total variance in medullation index. Late-born lambs were more highly medullated than those born earlier. That trend was significant in Flock B.

1.4.1.4 Colour appraisals and measurements

Tables 1.4.12 to 1.4.17 indicate that position was generally the major factor controlling colour. The exception was in analyses A123, A12 and B12 where for greasy colour assessments, shearing or shearing X position interaction became the important sources of variation as the ranking of position changed among shearings. Occasionally, for

Table 1.4.12 Percentages of total variance due to different factors (with significance): *Greasy Colour Grade*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	0.0	2.1	2.9	40.7**	25.3**	55.0**	32.2**	28.8**	26.8**	27.6**	28.3**
Sex (S)	0.1	0.2	5.3	1.5	8.7	0.4	0.0	0.0	27.0	0.0	♀♀ only
Birth rank (BR)	0.3	0.5	0.0	0.0	0.0	0.0	0.0	1.2	1.3	0.0	0.0
Dam age	0.5**	0.4	0.7	1.8**	0.5	0.4	3.8*	0.0	0.0	1.6*	0.0
Birth date						**	*				
Shearing (SHG)	42.3	24.9	0.0								
Sire	0.0	0.0	2.9			1.7	5.8	0.0	1.6	0.7	9.8
SHG x POS	23.8**	29.5**	25.5**								
SHG x Sire	0.9**	1.4**	4.1**								
SHG x S	0.0	0.0	3.9**								
SHG x BR	0.0	0.0	0.0								
Sire x S	0.0	0.0	0.1			1.7*	1.2	1.5	0.8	0.0	
Sire x BR	0.0	0.6	0.8			0.0	0.5	0.3	0.7	1.6	11.8**
BR x S	0.0	0.5	3.7**			0.0	3.8*	0.9	0.0	0.0	
Flock				1.1	15.9						
Sire/flock				5.2**	2.1**						
Flock x S				0.0	7.3**						
Residual	32.1	40.0	50.3	49.8	40.2	40.9	52.7	67.3	41.9	68.6	50.2
Res. mean sq.	0.31	0.29	0.60	0.62	0.35	0.25	0.83	0.31	0.37	0.36	0.37

* $p<0.05$, ** $p<0.01$

Table 1.4.13 Percentages of total variance due to different factors (with significance): *Scoured Colour Grade*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	38.0**	48.0**	36.0*	37.8**	52.7**	50.0**	34.8**	58.8**	44.3**	29.0**	68.3**
Sex (S)	0.8	0.7	0.7	0.5	3.7	0.5	0.0	0.9	11.4	0.0	♀♀ only
Birth rank (BR)	0.1	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.1	0.0	0.0
Dam age	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.3	0.0	0.0
Birth date			*	*		*	**				
Shearing (SHG)	2.9	5.8	0.1								
Sire	0.2	0.1	6.4			0.0	9.5	0.0	2.3	4.4	3.3
SHG x POS	5.8**	0.2	1.7*								
SHG x Sire	1.5**	0.8	2.2*								
SHG x S	0.0	0.0	2.6**								
SHG x BR	0.9*	1.7**	0.0								
Sire x S	1.0*	0.5	2.7*			1.7	5.9**	0.0	3.9**	1.3	
Sire x BR	0.6	0.3	1.3			0.8	3.9*	1.2	0.9	0.0	5.0*
BR x S	0.0	0.3	0.5			1.8*	0.4	0.0	0.0	1.0	
Flock				11.6	0.0						
Sire/flock				9.3**	3.2**						
Flock x S				0.0	4.0**						
Residual	48.2	41.7	46.0	40.8	36.4	44.0	45.2	39.1	36.8	64.3	23.5
Res. mean sq.	0.98	0.95	1.63	1.99	0.80	1.23	2.25	0.59	0.88	1.04	1.41

* $p<0.05$, ** $p<0.01$

Table 1.4.14 Percentages of total variance due to different factors (with significance): x

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	43.1**	47.6**	50.7**	42.5**	54.5**	47.8**	59.6**	62.4**	52.7**	52.2**	62.2**
Sex (S)	0.5	0.7	3.9	0.7	4.6	0.4	0.2	1.3	15.3	0.0	♀♀ only
Birth rank (BR)	0.0	0.0	0.0	0.1	0.0	1.4	0.0	1.5	0.0	0.4	0.0
Dam age	1.0**	1.8**	0.0	0.1	0.0	3.6**	0.0	0.0	0.5	0.0	0.0
Birth date		**	**	*	**	**	**				
Shearing (SHG)	7.8	7.7	0.0								
Sire	0.8	0.0	3.5			1.7	4.9	0.0	0.0	3.1	3.0
SHG x POS	5.1**	0.0	6.7**								
SHG x Sire	1.3**	1.5**	0.9								
SHG x S	0.0	0.0	1.1*								
SHG x BR	1.6**	2.7**	0.0								
Sire x S	0.2	0.1	0.7			0.0	2.9**	0.3	2.3*	1.2	
Sire x BR	1.6**	2.5**	0.0			2.1*	0.5	3.1**	4.4**	0.1	8.1**
BR x S	0.0	0.4	0.3			0.6	0.8	0.0	0.0	0.2	
Flock				27.3	12.8						
Sire/flock				3.8**	1.6**						
Flock x S				0.0	3.6*						
Residual	37.0	35.1	32.2	25.5	23.0	42.5	31.0	31.5	24.8	42.9	26.8
Res. mean sq.	3.32	3.74	6.37	7.88	2.76	4.71	9.09	2.68	2.84	2.34	3.78

* $p<0.05$, ** $p<0.01$

Table 1.4.15 Percentages of total variance due to different factors (with significance): *Y*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	41.4**	44.5**	49.0*	43.1**	49.5**	46.2**	59.8**	54.2**	50.4**	53.4**	62.0**
Sex (S)	0.3	0.4	3.7	0.6	3.7	0.0	0.2	0.8	14.7	0.0	♀♀ only
Birth rank (BR)	0.0	0.0	0.1	0.1	0.0	1.7	0.0	0.7	0.0	0.3	0.0
Dam age	1.3**	2.3**	0.0	0.1	0.0	4.4**	0.0	0.1	0.1	0.0	0.0
Birth date		*	**	*	**	**	**				
Shearing (SHG)	5.2	4.7	0.2								
Sire	0.2	0.0	3.1			1.5	4.7	0.0	0.0	3.0	2.7
SHG x POS	4.9**	0.0	7.9**								
SHG x Sire	1.7**	1.8**	1.2*								
SHG x S	0.0	0.0	1.0*								
SHG x BR	1.5**	2.4**	0.0								
Sire x S	0.2	0.0	0.5			0.0	3.0**	0.0	1.8*	1.4	
Sire x BR	2.0**	3.1**	0.0			2.6*	0.7	3.3**	4.1**	0.0	8.1**
BR x S	0.1	0.6	0.2			0.7	0.7	0.0	0.0	0.0	
Flock				26.1	12.6						
Sire/flock				3.7**	1.4**						
Flock x S				0.0	3.8**						
Residual	41.2	40.3	33.2	26.3	29.1	42.9	30.9	41.0	29.0	41.8	27.1
Res. mean sq.	4.06	4.79	7.32	9.04	3.78	5.57	10.2	3.90	3.56	2.43	4.08

* p<0.05, ** p<0.01

Table 1.4.16 Percentages of total variance due to different factors (with significance): z

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	43.3**	49.0**	37.4*	32.8**	48.9**	50.6**	41.2**	61.5**	43.9**	47.0**	63.4**
Sex (S)	0.0	0.1	4.4	0.7	2.7	0.1	1.2	0.0	18.3	0.0	♀♀ only
Birth rank (BR)	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.0	0.0
Dam age	0.4*	0.8*	0.0	0.3	0.0	1.1*	0.0	0.0	0.4	0.0	0.0
Birth date		*	**		**	**	**				
Shearing (SHG)	6.6	5.9	4.2								
Sire	0.5	0.8	5.3			0.9	9.4	0.0	0.5	1.7	1.7
SHG x POS	4.7**	0.0	3.7**								
SHG x Sire	1.2**	0.5	3.1**								
SHG x S	0.1	0.0	1.1*								
SHG x BR	0.7*	1.3*	0.0								
Sire x S	0.5	0.0	1.2*			0.2	4.6**	0.6	3.1**	1.3	
Sire x BR	1.6**	2.3**	0.3			1.8*	0.8	3.3**	4.8**	0.3	9.9**
BR x S	0.0	0.9*	0.7			0.9	0.2	0.5	0.0	1.0	
Flock				30.6	11.2						
Sire/flock				6.4**	2.5**						
Flock x S				0.3	7.2**						
Residual	40.5	38.3	38.6	28.8	27.5	44.0	42.5	34.1	29.1	48.7	25.1
Res. mean sq.	7.47	8.13	15.94	19.18	6.30	10.68	23.86	5.32	6.49	5.97	9.89

* $p<0.05$, ** $p<0.01$

Table 1.4.17 Percentages of total variance due to different factors (with significance): Y-Z

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	24.0**	28.4**	9.2**	8.2**	22.3**	34.9**	2.2*	24.9**	18.9**	23.2**	51.3**
Sex (S)	0.0	0.0	3.2	0.5	0.0	0.0	2.3	0.0	14.7	1.7	♀♀ only
Birth rank (BR)	0.1	0.0	0.0	0.5*	0.0	0.0	1.6	0.0	0.0	0.0	0.0
Dam age	0.0	0.1	0.0	0.6	0.0	0.8	0.7	0.0	0.4	0.0	0.0
Birth date		*					*				
Shearing (SHG)	4.3	3.5	11.4								
Sire	1.0	1.7	7.4			0.0	12.7	1.7	1.7	2.8	4.2
SHG x POS	2.6**	0.0	0.0								
SHG x Sire	0.8	0.0	3.4**								
SHG x S	0.6	0.0	0.7								
SHG x BR	0.0	0.0	1.0								
Sire x S	1.0*	1.1	3.9**			6.2**	6.3*	0.0	5.0*	0.5	
Sire x BR	1.0*	1.3	2.6*			2.6*	1.5	0.1	4.3*	1.3	14.3**
BR x S	0.0	0.6	1.5*			0.4	0.0	0.2	1.8	2.4	
Flock				25.5	1.6						
Sire/flock				10.1**	2.8**						
Flock x S				1.0	10.0**						
Residual	64.6	63.3	55.8	53.7	63.3	55.1	72.6	73.2	53.2	68.1	30.2
Res. mean sq.	1.85	2.04	3.10	4.80	2.07	1.82	6.25	2.17	1.56	1.44	2.22

* $p<0.05$, ** $p<0.01$

Y-Z value, shearing (B12), flock (AB1) and sire (B1) appeared to be important sources of variations.

Overall, lateral positions ranked better for assessed and measured scoured colour. That was in parallel with higher medullation indices on lateral samples. In scoured colour, the back position was generally poor in all assessments and measurements while the mid-side sample was generally whiter than other lateral positions. The shearing X position interaction controlled a large proportion of the variance in greasy colour but not for other criteria of colour. At later shearings, greasy wool tended to be whiter in dorsal positions and yellower in lateral ones.

There were considerable shearing differences in greasy colour in Flock A compared with Flock B. In the first shearing (AB1), between-flock differences were lower for greasy colour grade while contributed higher percentages to the total variance in assessed and measured scoured colour compared with the second shearing (AB2). In general, Flock A had whiter greasy and scoured wool than Flock B. Whiter colour and higher reflectances (X, Y and Z) in Flock A may be a result of genetic differences, perhaps associated with considerably higher levels of medullation in this flock, or that the environmental conditions did not favour the development of discolouration in the period prior to shearing.

Sex differences were usually small while showing higher proportions to the total variance in colour in B2. Flock X sex interaction was significant in the second shearing while shearing X sex interaction was significant in Flock B. This is probably due to the sexes being grazed separately and coming under different environmental influences.

Birth rank had no effect on colour in both flocks. Age of dam was significant at times, but the size of the effects was small and the direction was inconsistent with no clear pattern. Late-born lambs had significantly better assessed and measured scoured colour at the first shearing.

The sire within-flock difference was significant in both flocks. The among-sire variance was occasionally high. When flocks were analysed separately the presence of sire X sex and sire X birth rank interactions often limited the sire main effects for greasy and scoured colour. The reason for these interactions is not clear.

1.4.1.5 Staple length

There were substantial flock differences in staple length. The variance component was much larger in AB2 than AB1 (Table 1.4.18). In Flock A, the among-shearing effect was the main source of variation. The number of days growth represented by the fleeces differed between farms and among shearings. This, together with variation in growth rate due to season and nutrition, is probably the cause.

Position was also significant over the three shearings. In Flock B, staples tended to be longer on lateral positions. A similar trend was found at the second and third shearings in Flock A. Shearing X position interaction was significant in both flocks.

The sire within-flock variation was significant in the first and second shearings (AB1 and AB2). The among-sire variations were larger in Flock B and at later fleeces. The ranking of sires changed across shearings as shearing X sire interaction appeared to be significant in both flocks.

Sex had little effect on staple length. The few significant sex and shearing X sex effects might be due to different management and different shearing times for rams and ewes after the first shearing. The ranking of sires was inconsistent across sexes in both flocks.

As could be expected, the contribution of birth rank to the total variance was larger in the first than in the later fleeces. Singles generally had longer staples in the first shearing and shorter staples in the second and third shearings. There was a significant shearing X birth rank effect in both flocks. Also, sire X birth rank interaction appeared to be often significant. There was a trend for single rams and twin ewes to have longer staples as indicated by the significant birth rank X sex interaction (B12, B1, B2, A2).

Table 1.4.18 Percentages of total variance due to different factors (with significance): *Staple Length*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	3.4	5.2	6.8	3.3**	5.3**	13.0**	8.0**	9.7**	20.4**	21.3**	22.8**
Sex (S)	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	4.5*	♀♀ only
Birth rank (BR)	0.0	0.0	0.0	8.2**	0.1	8.9	6.1	0.0	0.0	3.5*	1.4
Dam age	0.0	2.1**	0.1	9.5**	3.7**	10.2**	0.2	0.7	0.0	7.7**	0.0
Birth date	*	**		**		**	**			**	
Shearing (SHG)	40.3	29.3	5.4								
Sire	0.0	0.0	1.7			0.0	2.0	0.0	5.2	10.1	12.0
SHG x POS	5.3**	2.1**	7.8**								
SHG x Sire	6.0**	3.6**	2.8**								
SHG x S	2.0**	0.2	0.6								
SHG x BR	4.3**	5.1**	5.2**								
Sire x S	2.1**	4.3**	9.0**			7.1**	20.1**	7.4**	4.8*	1.1	
Sire x BR	2.3**	6.7**	4.3**			6.5**	0.1	14.0**	11.4**	0.8	20.2**
BR x S	0.1	0.5	3.6**			0.0	2.6*	3.0*	3.3*	0.0	
Flock				16.8	63.5**						
Sire/flock				5.1**	3.3**						
Flock x S				1.0	0.0						
Residual	34.3	41.0	52.9	56.0	23.3	54.2	60.B	65.2	54.9	51.0	43.6
Res. mean sq.	3.09	2.50	2.85	2.70	3.41	2.30	2.14	2.36	3.39	3.52	3.36

* $p<0.05$, ** $p<0.01$

The offspring of older dams generally had longer staples in the first and second shearings but the trend was reversed in the third shearing. The age of dam effect was occasionally significant, the variance component being larger in Flock A and smaller in later fleeces.

Date of birth was significant in both flocks; lambs born earlier in the season generally had longer staples at first shearing. In A3, it was found that the sire whose progeny were born late in the season had longer staples. When offspring of that sire were omitted from the analysis and when sire was fitted earlier birth date was non-significant while the sire effect was highly significant.

1.4.1.6 Yield

Position was generally the main source of variation in yield (Table 1.4.19). Dorsal positions had higher yield than laterals in both flocks. Higher discolouration found in greasy samples might be associated with poor yield in the posterior parts of the body. No consistent dorso-lateral trend was found for greasy discolouration. The ranking of positions changed among shearings as the shearing X position interaction was found to be significant; however the size of the effect was small.

There were considerable flock differences in yield, the variance component being large at the first shearing (AB1). The sire within-flock difference was significant and the variance component was higher in the second shearing (AB2). The among-sire variations increased in the third shearing. The ranking of sires changed across shearings as the shearing X sire interaction was found to be significant with small variance components.

Flock A data showed that twins had higher yield than singles, the birth rank variance component being larger in Flock A whereas sire X birth rank interaction was significant in Flock B with a larger variance component. The reason for such a trend is not clear.

Age of dam effects, although significant at times, were small in magnitude. Date of birth was occasionally significant as late-born

Table 1.4.19 Percentages of total variance due to different factors (with significance): *Yield*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	25.0**	20.0**	18.5*	18.1**	23.0**	19.9**	16.2**	30.2**	25.0**	39.5**	67.5**
Sex (S)	0.5	0.0	0.8	0.0	0.0	0.0	0.0	0.3	1.2	7.7	♀♀ only
Birth rank (BR)	6.1	7.0	0.0	0.5	0.6	6.6	0.0	7.0	0.0	3.6	0.0
Dam age	1.3**	1.7**	0.8	0.9	0.0	0.6	1.5	2.8**	0.0	0.4	0.7
Birth date		*		**		**					*
Shearing (SHG)	0.3	4.5	0.0								
Sire	0.0	0.0	0.0			0.3	0.0	1.4	0.0	3.8	4.0
SHG x POS	4.4**	2.3**	1.8*								
SHG x Sire	2.7**	1.4*	4.3**								
SHG x S	1.9**	0.0	0.0								
SHG x BR	0.0	0.0	0.0								
Sire x S	0.9*	0.6	0.7			0.3	0.0	0.4	0.9	1.9*	
Sire x BR	0.8	0.6	6.0**			0.0	6.4*	1.7	9.1**	0.2	7.6**
BR x S	0.0	0.7	0.0			1.4	0.0	0.0	0.0	0.3	
Flock				20.5**	8.7						
Sire/flock				0.4	4.1**						
Flock x S				0.5	1.5*						
Residual	56.3	61.3	67.2	59.1	62.0	71.1	75.9	56.2	63.9	42.6	20.2
Res. mean sq.	24.3	25.9	26.5	28.37	24.25	28.19	32.76	21.73	20.57	20.74	10.20

* $p<0.05$, ** $p<0.01$

lambs had higher yield than those born earlier.

1.4.1.7 Bulk and resilience

Flock A samples had higher bulk (22.0 vs 20.57) and resilience (7.68 vs 7.50) than Flock B samples. Between-flock differences were the major source of variation at the first shearing (AB1) particularly for bulk (Tables 1.4.20 and 1.4.21).

Position had a significant effect in both flocks. In Flock B, bulk and resilience generally tended to be higher dorsally and towards the posterior parts of the body. Shearing X position interaction occurred in both flocks. In Flock A, bulk and resilience tended to decrease on shoulder and britch positions at later shearings while increasing on the back.

Due to the progeny of one sire being born late in the season, there is a confounding of sire and birth-date effects. When offspring of this sire were omitted from the data and when sire was fitted before birth date the regression on birth date was non-significant while the sire effect was highly significant. This together with information from other breeds (Bigham *et al.*, 1985) indicates that genetic effects inherited from the sire are important.

Highly significant sire within-flock variation accounted for higher percentages to the total variance in the second shearing (AB2) and for bulk than resilience. Among-sire variation was almost negligible in Flock B. The ranking of sires was not consistent across shearings as the interaction of shearing X sire was significant in Flock A.

Sex had little effect on bulk and resilience. Sire X sex interaction was significant at times for bulk. Sex might be confounded with some environmental factors after the first shearing when ewes and rams were separated.

In Flock A, singles generally had higher bulk and resilience. It is surprising that sire X birth rank interaction was significant in both flocks, the variance component being larger in Flock B. This

Table 1.4.20 Percentages of total variance due to different factors (with significance): *Bulk*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	12.7*	21.2**	24.0*	6.3**	19.8**	22.4**	4.9**	23.1**	17.2**	27.4**	16.0**
Sex (S)	0.0	0.0	0.0	0.0	1.5	0.0	0.0	1.8	0.0	0.0	♀♀ only
Birth rank (BR)	2.7	2.5	0.0	0.0	1.7**	0.5	0.0	4.6	0.0	2.9	0.0
Dam age	0.0	0.6	0.0	2.1*	0.0	0.6	0.2	0.0	0.0	0.3	2.0
Birth date					**			**		**	*
Shearing (SHG)	0.0	0.0	0.6								
Sire	11.1	9.1	0.0			8.7	0.0	19.2	0.0	15.8	0.9
SHG x POS	12.6**	2.6**	2.7*								
SHG x Sire	3.9**	4.9**	0.3								
SHG x S	0.2	0.4	0.0								
SHG x BR	0.0	0.1	0.3								
Sire x S	0.4	0.2	4.6**			2.7*	4.6*	0.0	3.8*	1.5	
Sire x BR	3.0**	3.7**	13.4**			8.3**	3.4	0.5	21.1**	2.6*	40.9**
BR x S	0.2	0.0	0.4			0.0	2.5	0.0	1.2	0.1	
Flock				9.1**	4.7						
Sire/flock				1.8*	11.3**						
Flock x S				0.0	0.0						
Residual	53.3	57.7	53.6	80.7	61.0	56.9	84.5	50.8	56.8	49.5	40.2
Res. mean sq.	2.57	2.42	2.74	15.5	2.90	2.60	23.90	2.30	2.71	2.81	2.36

* $p<0.05$, ** $p<0.01$

Table 1.4.21 Percentages of total variance due to different factors (with significance): *Resilience*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	0.8	1.5	11.9	**2.5	**8.0	**9.0	*3.2	**3.8	**9.1	**13.8	**7.7
Sex (S)	0.0	0.3	1.3	0.0	0.2	0.0	0.0	0.4	1.0	0.0	♀♀ only
Birth rank (BR)	2.8	2.2	0.0	0.0	*1.4	0.3	0.0	6.4	0.0	3.7	0.0
Dam age	0.0	0.0	0.0	**3.8	0.0	*2.8	0.8	0.1	0.0	*1.8	*3.1
Birth date	**	**	**		**			**	*	**	**
Shearing (SHG)	3.0	0.0	2.5								
Sire	9.5	7.9	0.0			2.8	0.0	15.2	0.0	14.9	2.8
SHG x POS	**8.6	**5.0	*2.5								
SHG x Sire	*1.4	1.1	0.0								
SHG x S	0.0	0.0	0.0								
SHG x BR	0.3	0.5	0.8								
Sire x S	0.0	0.0	1.3			1.5	3.9	0.0	0.4	0.6	
Sire x BR	**2.4	*2.7	**9.7			**5.8	3.8	0.0	**19.8	2.3	**34.4
BR x S	0.3	0.0	0.0			0.0	*3.3	0.0	0.0	0.7	
Flock				7.4	0.4						
Sire/flock				0.1	**8.5						
Flock x S				0.0	0.2						
Residual	70.9	78.8	69.9	86.2	81.3	77.7	85.0	74.1	69.8	62.2	51.8
Res. mean sq.	0.75	0.71	0.65	2.27	0.63	0.76	3.16	0.63	0.60	0.82	0.66

* $p<0.05$, ** $p<0.01$

interaction was the main source of variation in B2 and B3 and controlled 40.9% of the total bulk variance in B3 ewes. Ranking of sires was not consistent for single and twin offspring; while single progeny of sire 9 had higher bulk (1.93 vs -1.55), single progeny of sire 6 had lower bulk (-0.14 vs 1.31). For all traits studied it was found that sire X birth rank interaction was significant and contributed relatively higher percentages to the total variance in several models, particularly in B3 ewes. In the latter model, sire X birth rank interaction tended to be always significant and controlled 5% - 41% of the total variance in all traits studied. No explanation has been found for such a trend. These interactions with genotype could be a major difficulty in selecting for bulk (or other traits) if they occur commonly in larger sets of data.

1.4.1.8 Lustre grade

Position was the main source of variation in both flocks (Table 1.4.22). Generally, in Flock B more lustre was seen on lateral positions and on the anterior parts of the body. Flock A showed a similar trend in the second and third shearings. There were considerable differences among shearings in lustre, and the shearing X position interaction was significant in both flocks. In Flock A, the SH, MS and WH positions had higher lustre throughout the three shearings whereas SH and MS positions showed a similar trend in Flock B.

The sire within-flock variations were significant in the first and second shearings. The magnitude of the among-sire differences changed among shearings. Sex and birth rank had very little effect on lustre. Age of dam was significant in Flock A where the offspring of older dams had more lustrous wool than those of younger dams.

1.4.1.9 Greasy and clean wool per unit area

Tables 1.4.23 and 1.4.24 indicate that flock and shearing effects were major sources of variation reflecting differences in the duration of the period of wool growth as well as the environment during that period. Position effect was also an important source of variation in both flocks with more wool produced on the back position. The ranking

Table 1.4.22 Percentages of total variance due to different factors (with significance): *Lustre Grade*

Sources of variation	A123	A12	B12	AB1	AB2	A1	B1	A2	B2	A3	B3
Position (POS)	$\overset{**}{9.1}$	4.8	$\overset{*}{27.4}$	$\overset{**}{35.0}$	$\overset{**}{30.5}$	$\overset{**}{10.9}$	$\overset{**}{45.5}$	$\overset{**}{12.9}$	$\overset{**}{37.4}$	$\overset{**}{15.5}$	$\overset{**}{40.7}$
Sex (S)	0.0	0.0	0.0	0.3	0.0	0.5	0.0	3.6	0.0	1.1	♀♀ only
Birth rank (BR)	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Dam age	$\overset{**}{4.3}$	$\overset{**}{5.0}$	0.0	0.0	$\overset{*}{1.7}$	$\overset{**}{4.1}$	0.0	$\overset{**}{4.7}$	0.0	$\overset{*}{2.4}$	0.4
Birth date	**							*	*	*	
Shearing (SHG)	8.3	15.B	22.5								
Sire	3.2	0.5	0.0			2.3	2.1	1.1	2.1	9.4	0.0
SHG x POS	$\overset{**}{3.3}$	$\overset{**}{4.2}$	$\overset{**}{2.8}$								
SHG x Sire	0.8	0.2	$\overset{**}{2.4}$								
SHG x S	$\overset{**}{2.3}$	$\overset{**}{3.4}$	0.0								
SHG x BR	0.0	0.0	0.0								
Sire x S	$\overset{*}{1.3}$	$\overset{*}{2.1}$	0.2			0.6	2.6	1.2	$\overset{*}{2.7}$	0.6	
Sire x BR	0.0	0.2	0.4			2.2	1.1	1.6	0.0	0.0	$\overset{**}{17.7}$
BR x S	0.0	0.0	0.5			0.0	0.0	0.0	1.4	0.9	
Flock				$\overset{*}{3.7}$	0.0						
Sire/flock				$\overset{**}{3.8}$	$\overset{*}{2.0}$						
Flock x S				0.0	$\overset{*}{1.6}$						
Residual	67.4	63.8	43.8	57.2	64.1	79.4	48.6	74.9	56.3	70.1	41.2
Res. mean sq.	0.20	0.17	0.22	0.16	0.23	0.17	0.15	0.19	0.26	0.28	0.19

* $p<0.05$, ** $p<0.01$ &

of positions changed considerably between shearings as position X shearing interaction was highly significant in both flocks.

Differences in the amount of wool grown on different positions were observed in Romney (Kent) lambs (Henderson, 1953). Cockrem and Wickham (1960) and Cockrem (1962) attributed 50% of the variation in wool output over the body to the variation in blood supply at various positions as measured by skin temperature.

The effect of sire within-flock was significant at the first and second shearings. The among-sire variance component increased at the third shearing in both flocks. The ranking of sires was inconsistent among shearings in Flock A and between sexes in Flock B.

Rams in both flocks had lower greasy and clean wool per unit area at the first and second shearings. At the third shearing, Flock A rams produced more wool in greasy and clean conditions. Different management of the two sexes after the first shearing perhaps largely determined effects at later shearings and shearing X sex interactions.

Singles had higher greasy and clean wool production than twins in both flocks, the variance components being higher at the first shearing. Sire X birth rank interaction was found to be significant at the second and third shearings. Highly significant shearing X birth rank interactions in A123 and B12 were due to the recovery of wool production in twins as they aged after being restricted as lambs.

The offspring of older dams generally had higher greasy and clean wool per unit area than those of younger dams. That trend was significant at the first shearing, the variance component being larger in Flock A.

Early-born lambs had significantly higher wool production than those born later at the first shearing (A1) while the opposite trend was significant at the third shearing (A3).

Table 1.4.23 Percentages of total variance due to different factors (with significance): *Greasy Wool per Unit Area*

Sources of variation	# A123	+ A23	+ B12	# AB1	+ AB2	# A1	+ B1	+ A2	+ B2	+ A3	+ B3
Position (POS)	2.3	5.0	8.6	12.7**	11.0**	0.0	48.5**	23.8**	25.3**	34.8**	42.0**
Sex (S)	2.2	0.0	3.3	0.8	12.0	1.8	1.5	33.4	9.5	0.0	♀♀ only
Birth rank (BR)	0.0	0.0	0.0	11.0**	0.0	16.4	7.4	0.0	0.0	0.0	0.0
Dam age	0.7*	0.0	0.0	9.1**	0.8*	17.0**	1.5*	0.2	1.8	0.0	0.2
Birth date		*		**		**				**	
Shearing (SHG)	39.4	56.5	30.2								
Sire	1.4	0.9	2.2			0.0	2.7	1.4	3.0	5.8	9.7
SHG x POS	12.5**	8.2**	16.9**								
SHG x Sire	3.1**	2.3**	0.3								
SHG x S	5.1**	7.8**	1.2*								
SHG x BR	2.4**	0.3	2.1**								
Sire x S	0.0	0.3	1.0*			0.0	3.2**	0.5	7.2**	3.1	
Sire x BR	1.1	1.3**	3.6**			2.4	1.2	3.7*	4.9**	3.1	8.6**
BR x S	0.1	0.2	0.0			0.0	0.0	0.1	0.0	0.2	
Flock				4.7	35.8						
Sire/flock				2.6*	3.6**						
Flock x S				0.0	2.4**						
Residual	29.7	17.3	30.6	59.0	34.5	62.3	34.0	37.1	48.3	53.0	39.5
Res. mean sq.	21.04	23.93	19.97	16.33	25.57	13.13	13.88	16.39	24.96	30.57	18.64

(+ 4 positions are included: SH, MS, BR & BK; # 2 positions are included: SH & MS)
* $p<0.05$, ** $p<0.01$

Table 1.4.24 Percentages of total variance due to different factors (with significance): *Clean Wool per Unit Area*

Sources of variation	# A123	+ A23	+ B12	# AB1	+ AB2	# A1	+ B1	+ A2	+ B2	+ A3	+ B3
Position (POS)	2.0	11.7	13.5	10.3**	15.2**	0.0	50.6**	34.8**	27.9**	42.2**	62.8**
Sex (S)	0.0	0.0	3.5	0.9	10.9	1.0	1.2	24.8	10.3	0.8	♀♀ only
Birth rank (BR)	0.0	0.0	0.2	6.9**	0.0	12.3	5.6	0.0	0.0	0.0	0.0
Dam age	0.4	0.0	0.0	9.7**	0.7*	15.6**	2.4*	0.0	0.8	0.0	0.0
Birth date				**		**				**	
Shearing (SHG)	29.4	42.6	27.7								
Sire	1.6	0.4	1.4			0.0	4.0	0.0	0.8	7.8	3.6
SHG x POS	18.4**	8.7**	15.0**								
SHG x Sire	4.3**	4.0**	0.3								
SHG x S	6.9**	11.0**	1.2*								
SHG x BR	2.8**	0.3	1.4**								
Sire x S	0.0	0.2	0.8			0.0	2.7*	0.7	4.9*	0.8	
Sire x BR	1.3	1.8**	3.2**			3.1	0.0	4.9**	4.5*	3.4*	7.7**
BR x S	0.8	0.7*	0.0			0.0	0.0	0.5	0.0	1.7	
Flock				12.9	37.6						
Sire/flock				3.7**	1.8**						
Flock x S				0.0	0.9*						
Residual	32.1	18.7	31.7	55.7	33.0	68.0	33.7	34.3	51.0	43.3	26.0
Res. mean sq.	14.02	17.44	16.55	11.87	20.02	8.27	12.10	12.18	20.85	22.20	12.10

(+ 4 positions are included: SH, MS, BR & BK; # 2 positions are included: SH & MS)
* $p<0.05$ ** $p<0.01$

1.4.1.10 Fleece weight

First and third shearing fleece weight data from Flock A were analysed (Tables 1.4.25 and 1.4.26). For first greasy fleece weight (GFW1) the main source of variation was the birth rank effect. Singles had significantly heavier GFW1 than twins and the birth-rank accounted for 45.1% of the total variance.

Sex differences were highly significant for the GFW3 and CFW3, rams having heavier fleeces than ewes. At the third shearing, rams also had longer staples, higher yield, higher medullation indices and more clean wool per unit area despite being shorn one month earlier than ewes at this shearing. The rams probably also were given better nutrition before the third shearing. While these Drysdale rams had higher yields than the ewes, most studies of other breeds have found that rams have lower yielding wool (Turner and Young, 1969; Blair, 1981).

Sire effect contributed 5% to the total variance in GFW1 but made no contribution to GFW3 or CFW3. The implication of this is that GFW3 and CFW3 have zero heritability in this flock but this needs to be verified with far larger numbers of sires and offspring.

Dam-age controlled little variance and was non-significant but there was a tendency for the offspring of older dams to have heavier fleeces as lambs (GFW1) and at the third shearing (GFW3 and CFW3). Early-born lambs had significantly heavier GFW1 than those born later.

Table 1.4.25 Least squares means and effects for *first and third fleece weights* in Flock A

	GFW1	GFW3	CFW3
Mean	1.38	2.10	1.70
Sex: Male	+0.02	+0.19	+0.18
Birth rank: Single	+0.15	+0.02	0.00
Dam age: 2-yr	-0.06	-0.12	-0.08
Birth date	-0.01	+0.01	+0.01

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects

Table 1.4.26 Percentages of total variance due to different factors in Flock A (with significance): *GFW1, GFW3 and CFW3*

Sources of Variations	d.f.	GFW1	GFW3	CFW3
Total	54			
Sex (S)	1	5.2	20.4 **	28.0 **
Birth rank (BR)	1	45.1 **	0.0	0.0
Dam age	1	2.0	6.0	3.1
Birth date	1	**		
Sire	4	5.0	0.0	0.0
Sire X BR	4	0.4	0.0	0.0
Sire X S	4	0.0	6.5	7.4
BR X S	1	0.0	0.0	0.0
Residual	37	42.3	67.1	61.5
Res. mean sq.		0.05	0.18	0.12

** $p<0.01$

1.4.2 Relations Among Fleece Traits

The correlations among various wool characteristics are shown in Tables 1.4.27-1.4.31.

1.4.2.1 Kemp score

High kemp score generally had low correlations with harsh handle. The small size of the correlations is probably due to the variation in handle arising mainly from fibre diameter differences and the level of continuous medullated fibres as reported by Roberts (1956), Von Bergen (1963) and Shah and Whiteley (1971). Problems of subjective assessment may also contribute. Kemp score had generally weak positive correlations with medullation index. While kemps would contribute substantially to medullameter reflectance, continuous medullated fibres also contribute to this reflectance and if kemp is not present the primary follicles which produce kemps are probably occupied by continuous medullated fibres.

Kemp was associated with higher X, Y and Z reflectances and reduced Y-Z. Kemp score tended to increase as staple length decreased. Slee (1959) showed that staple length was diminished by fibre shedding in the Wiltshire Horn X Scottish Blackface crosses. Kemp also tended to be associated with higher bulk and resilience and lower lustre.

1.4.2.2 Handle grade

Negative correlations between handle and medullation index indicated that harsh handle is usually associated with higher medullation. This correlation was positive (0.23) as estimated from the average of the first fleece in Flock A. The proportion of non-medullated fibres is often low in Drysdale samples and many low-diameter fibres are medullated. These would not affect the handle adversely but would influence the medullation index.

Soft handle was found to be associated with both subjective greasy and scoured whiteness. The magnitude of these correlations generally increased as whiteness increased from greasy samples. The

Table 1.4.27 Correlations between shoulder wool traits at shearings 1, 2 and 3 (pooled over sexes and flocks)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS																
HG	-0.14 -0.20 -0.16															
MI	0.05 0.33 0.01	-0.02 -0.20 -0.21														
GCG	-0.02 0.06 0.03	0.39 0.28 0.04	-0.03 0.24 0.33													
SCG	-0.01 0.18 0.27	0.18 0.17 0.06	0.08 0.15 0.01	0.51 0.38 0.27												
X	0.08 0.26 0.28	0.01 0.08 -0.12	0.13 0.54 0.43	0.41 0.49 0.43	0.73 0.60 0.52											
Y	0.08 0.25 0.29	-0.01 0.00 -0.13	0.15 0.55 0.49	0.37 0.50 0.43	0.71 0.55 0.52	0.99 0.99 1.00										
Z	0.04 0.29 0.34	0.03 0.04 -0.03	0.13 0.41 0.39	0.50 0.54 0.39	0.83 0.74 0.62	0.95 0.94 0.96	0.93 0.91 0.95									
Y-Z	-0.08 -0.24 -0.27	-0.09 -0.06 -0.17	-0.07 -0.16 -0.07	-0.54 -0.44 -0.17	-0.81 -0.77 -0.60	-0.66 -0.56 -0.58	-0.64 -0.52 -0.56	-0.84 -0.82 -0.80								
STL	0.02 -0.11 -0.22	-0.04 -0.21 -0.14	-0.05 0.19 0.41	-0.08 0.03 0.03	-0.24 0.01 -0.17	-0.06 0.16 0.05	-0.04 0.17 0.05	-0.12 0.13 0.01	0.20 -0.02 0.04							
YLD	0.17 0.26 -0.17	0.25 -0.06 -0.18	0.05 0.19 -0.07	0.23 0.24 0.16	0.06 0.17 -0.06	-0.02 0.12 -0.01	-0.03 0.12 0.00	0.05 0.18 -0.08	-0.14 -0.21 0.12	0.12 0.16 0.16						
GWA	0.16 -0.08 -0.17	-0.09 -0.29 -0.19	0.00 0.10 -0.03	-0.16 -0.19 -0.11	-0.23 -0.21 -0.11	-0.01 0.06 -0.10	0.00 0.11 -0.34	-0.13 -0.02 -0.17	0.27 0.20 0.23	0.41 0.46 0.24	-0.01 0.00 0.13					
CWA	-0.21 -0.02 -0.20	0.01 -0.29 -0.24	0.00 0.20 -0.05	-0.11 -0.10 -0.08	-0.21 -0.14 -0.11	-0.02 0.04 -0.09	-0.02 0.07 -0.08	-0.12 0.04 -0.18	0.24 0.02 0.24	0.42 0.50 0.26	0.32 0.28 0.45	0.94 0.96 0.94				
LG	-0.03 -0.33 0.00	0.17 0.26 0.35	0.03 -0.43 -0.44	0.36 0.03 -0.20	0.31 -0.09 -0.11	0.27 -0.25 -0.33	0.27 -0.26 -0.34	0.34 -0.22 -0.27	-0.35 0.06 0.09	0.15 -0.10 -0.25	0.11 -0.05 -0.10	-0.03 0.01 0.13	0.00 -0.01 0.08			
BUL	0.10 0.30 0.36	-0.19 -0.30 -0.23	0.37 0.29 0.17	-0.17 -0.02 0.09	0.03 0.21 0.26	-0.08 0.25 0.39	-0.09 0.25 0.39	-0.04 0.26 0.41	0.01 -0.21 -0.25	0.00 -0.16 -0.25	-0.11 -0.18 -0.37	-0.03 -0.17 -0.26	-0.08 -0.19 -0.35	-0.03 -0.24 -0.23		
RES	0.03 0.14 0.35	-0.13 -0.18 -0.13	0.30 0.08 0.02	-0.12 0.03 0.03	0.03 0.16 0.20	-0.13 0.17 0.25	-0.15 0.18 0.24	-0.06 0.21 0.28	-0.05 -0.20 -0.23	-0.10 -0.24 -0.34	-0.16 -0.24 -0.38	-0.13 -0.13 -0.23	-0.20 -0.17 -0.33	-0.06 -0.03 -0.12	0.91 0.86 0.92	

Correlations are arranged in descending order of shearings; 1, 2 and 3 respectively.
r>0.257 (p<0.05), r>0.333 (p<0.01).

Table 1.4.28 Correlations between mid-side wool traits at shearings 1, 2 and 3 (pooled over sexes and flocks)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS																
HG	-0.05															
	-0.27															
	-0.03															
MI	0.03	0.07														
	0.12	-0.38														
	-0.18	-0.33														
GCG	0.03	0.22	0.04													
	0.19	0.03	0.18													
	-0.17	0.27	0.05													
SCG	-0.06	0.09	0.16	0.39												
	0.23	0.06	0.04	0.20												
	0.07	0.26	-0.11	0.23												
X	0.06	0.09	0.25	0.38	0.69											
	0.33	-0.27	0.38	0.24	0.45											
	0.12	-0.11	0.33	0.22	0.49											
Y	0.09	0.06	0.25	0.36	0.67	0.99										
	0.27	-0.30	0.40	0.24	0.41	0.98										
	0.08	-0.12	0.33	0.21	0.47	1.00										
Z	0.03	0.13	0.20	0.38	0.74	0.93	0.91									
	0.31	-0.23	0.31	0.27	0.46	0.96	0.92									
	0.08	0.08	0.16	0.31	0.68	0.90	0.89									
Y-Z	0.07	-0.17	-0.07	-0.17	-0.62	-0.49	-0.45	-0.76								
	-0.20	0.06	-0.09	-0.25	-0.37	-0.65	-0.50	-0.81								
	-0.06	-0.27	0.06	-0.31	-0.74	-0.58	-0.55	-0.87								
STL	0.01	0.08	-0.15	-0.06	-0.11	0.00	0.03	-0.05	0.18							
	-0.02	-0.18	0.17	-0.03	0.07	0.16	0.19	0.18	-0.10							
	-0.38	-0.17	0.30	-0.01	-0.07	0.09	0.07	0.08	-0.06							
YLD	0.00	0.24	0.17	-0.03	-0.09	-0.13	-0.14	-0.02	-0.13	-0.04						
	0.25	-0.14	0.08	0.16	0.11	0.18	0.16	0.24	-0.28	0.14						
	-0.07	0.14	-0.05	0.25	0.06	0.07	0.08	-0.02	0.09	-0.04						
GWA	0.12	0.02	0.03	-0.02	-0.21	0.02	0.04	-0.01	0.11	0.64	-0.11					
	-0.24	-0.22	0.27	0.04	-0.19	0.05	0.11	-0.04	0.22	0.44	-0.17					
	-0.16	-0.20	0.15	-0.35	-0.11	0.06	0.07	-0.03	0.12	0.34	0.09					
CWA	0.06	0.09	0.06	-0.02	-0.24	-0.01	0.00	-0.01	0.06	0.62	0.24	0.95				
	-0.15	-0.24	0.28	0.08	-0.11	0.10	0.18	0.06	0.10	0.47	0.22	0.94				
	-0.18	0.14	0.11	-0.23	-0.11	0.07	0.08	-0.04	0.15	0.31	0.40	0.96				
LG	-0.06	0.09	0.08	0.09	0.22	0.36	0.35	0.35	-0.23	0.11	-0.04	0.09	0.08			
	-0.16	0.28	-0.31	-0.07	-0.06	-0.18	-0.15	-0.20	0.19	-0.15	-0.05	-0.08	-0.09			
	-0.24	0.45	-0.21	0.19	0.46	0.14	0.13	0.34	-0.55	0.08	0.07	-0.05	-0.03			
BUL	0.16	-0.23	0.29	0.12	0.11	0.11	0.13	0.08	-0.02	0.14	0.02	0.13	0.11	0.20		
	0.24	-0.35	0.27	0.24	0.17	0.30	0.30	0.31	-0.17	0.07	0.01	0.07	0.01	-0.32		
	0.25	-0.45	0.04	-0.15	-0.07	0.27	0.29	0.11	0.12	-0.13	-0.21	-0.03	-0.09	-0.34		
RES	0.07	-0.22	0.14	0.13	0.08	0.04	0.07	0.07	-0.06	0.06	-0.07	0.02	-0.03	0.11	0.91	
	0.14	-0.26	0.09	0.14	0.14	0.19	0.27	0.19	0.03	-0.06	0.05	0.09	0.09	-0.23	0.80	
	0.30	-0.28	-0.15	-0.22	-0.02	0.13	0.15	0.03	0.11	-0.23	-0.15	0.00	-0.05	-0.21	0.87	

Correlations are arranged in descending order of shearings; 1, 2 and 3 respectively.
$r>0.257$ ($p<0.05$), $r>0.333$ ($p<0.01$).

Table 1.4.29 Correlations between averages of wool traits at shearings 1, 2 and 3 in Flock A (pooled over sexes).

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS																
HG	-0.21															
	-0.58															
	-0.20															
MI	-0.04	0.23														
	0.25	-0.02														
	-0.35	-0.31														
GCG	0.16	0.24	0.03													
	0.32	-0.03	0.24													
	0.01	0.18	0.24													
SCG	0.30	0.04	0.26	0.51												
	0.35	-0.03	0.37	0.45												
	0.43	0.06	-0.07	0.26												
X	0.45	-0.11	0.38	0.38	0.71											
	0.29	-0.12	0.56	0.43	0.56											
	0.08	-0.23	0.49	0.39	0.53											
Y	0.46	-0.12	0.35	0.38	0.71	1.00										
	0.34	-0.19	0.50	0.48	0.52	0.93										
	0.08	-0.23	0.47	0.39	0.52	1.00										
Z	0.39	-0.10	0.38	0.45	0.81	0.95	0.94									
	0.41	-0.17	0.52	0.53	0.72	0.94	0.89									
	0.25	-0.08	0.27	0.48	0.76	0.91	0.91									
Y-Z	-0.03	-0.02	-0.26	-0.38	-0.68	-0.42	-0.38	-0.67								
	-0.35	0.10	-0.26	-0.40	-0.65	-0.51	-0.32	-0.72								
	-0.41	-0.12	0.05	-0.41	-0.86	-0.52	-0.52	-0.84								
STL	0.07	-0.22	-0.04	-0.19	-0.15	-0.05	-0.04	-0.15	0.33							
	-0.15	-0.31	-0.09	-0.08	-0.11	0.22	0.20	0.21	-0.06							
	-0.39	-0.09	0.42	-0.12	-0.38	-0.12	-0.13	-0.23	0.29							
YLD	-0.13	0.24	0.23	-0.02	-0.16	-0.20	-0.23	-0.19	0.03	-0.19						
	0.36	-0.15	0.19	0.35	0.26	0.28	0.16	0.27	-0.36	-0.19						
	-0.12	-0.17	0.24	0.18	-0.40	0.16	0.16	-0.06	0.31	0.20						
GWA	0.13	-0.03	-0.13	-0.07	-0.08	0.12	0.14	-0.01	0.35	0.60	-0.35					
	-0.24	-0.24	-0.03	-0.37	-0.21	0.06	0.07	-0.05	0.24	0.57	-0.24					
	-0.41	0.12	0.05	-0.09	-0.35	-0.18	-0.18	-0.29	0.35	0.41	0.31					
CWA	0.10	0.02	-0.11	-0.05	-0.09	0.09	0.10	-0.04	0.35	0.60	-0.17	0.98				
	-0.13	-0.30	0.01	-0.22	-0.14	0.12	0.08	0.02	0.10	0.52	0.10	0.93				
	-0.41	0.05	0.12	-0.04	-0.45	-0.12	-0.11	-0.28	0.43	0.44	0.58	0.95				
LG	-0.05	0.33	-0.06	0.45	0.26	0.17	0.17	0.17	-0.10	0.25	-0.03	0.17	0.20			
	-0.56	0.44	-0.30	-0.17	-0.34	-0.22	-0.24	-0.30	0.28	0.01	-0.24	0.14	0.13			
	0.04	0.45	-0.55	0.11	0.08	-0.24	-0.24	-0.07	-0.16	-0.20	0.01	0.24	0.21			
BUL	0.42	-0.28	0.24	0.10	0.45	0.33	0.33	0.34	-0.20	-0.01	-0.05	-0.08	-0.10	-0.12		
	0.64	-0.56	0.20	0.26	0.14	0.02	0.14	0.15	-0.12	-0.18	-0.05	-0.13	-0.14	-0.47		
	0.45	-0.27	-0.15	-0.05	0.34	0.14	0.14	0.25	-0.32	-0.54	-0.39	-0.58	-0.61	-0.41		
RES	0.23	-0.28	0.03	0.07	0.28	0.08	0.08	0.13	-0.22	-0.10	-0.09	-0.19	-0.21	-0.10	0.84	
	0.48	-0.47	-0.05	0.23	0.10	-0.08	0.05	0.04	-0.03	-0.16	-0.13	-0.06	-0.08	-0.28	0.90	
	0.43	-0.16	-0.29	0.00	0.24	-0.01	-0.01	0.14	-0.26	-0.56	-0.43	-0.51	-0.56	-0.25	0.95	

Correlations are arranged in descending order of shearings; 1, 2 and 3 respectively.
$r>0.271$ ($p<0.05$), $r>0.351$ ($p<0.01$).

Table 1.4.30 Correlations between averages of wool traits at shearings 1, 2 and 3 in Flock B (pooled over sexes)

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS																
HG	-0.10 -0.31 -0.24															
MI	0.24 0.34 0.12	-0.20 -0.54 -0.47														
GCG	0.22 -0.03 -0.21	0.50 0.30 0.49	0.06 0.13 0.05													
SCG	-0.07 0.04 -0.14	0.16 0.26 0.35	-0.06 0.11 0.12	0.45 0.51 0.52												
X	0.08 0.30 0.18	0.07 -0.05 -0.16	0.08 0.46 0.59	0.35 0.51 0.40	0.84 0.70 0.66											
Y	0.09 0.35 0.19	0.06 -0.10 -0.19	0.06 0.52 0.60	0.32 0.49 0.38	0.82 0.65 0.65	1.00 0.99 1.00										
Z	0.05 0.27 0.03	0.13 0.04 0.07	-0.01 0.44 0.43	0.44 0.55 0.52	0.92 0.77 0.82	0.97 0.97 0.93	0.95 0.94 0.92									
Y-Z	0.02 -0.05 0.19	-0.20 -0.25 -0.40	0.09 -0.18 -0.10	-0.53 -0.51 -0.58	-0.93 -0.77 -0.85	-0.79 -0.68 -0.63	-0.77 -0.59 -0.61	-0.92 -0.83 -0.86								
STL	-0.01 -0.21 -0.51	0.12 -0.07 -0.14	0.12 0.40 0.19	0.03 -0.04 0.06	-0.24 -0.13 0.40	-0.15 -0.01 0.23	-0.14 -0.02 0.23	-0.19 0.01 0.35	0.22 -0.03 -0.42							
YLD	0.27 0.10 -0.08	0.49 0.12 0.31	0.26 0.09 -0.26	0.34 0.32 0.44	-0.07 0.24 0.05	-0.15 0.20 -0.14	-0.17 0.17 -0.15	-0.09 0.24 -0.06	-0.04 -0.31 -0.07	0.29 0.12 0.05						
GWA	0.15 -0.09 -0.09	-0.23 -0.43 -0.51	0.30 0.37 0.06	-0.08 -0.21 -0.45	-0.26 -0.37 -0.01	-0.08 -0.14 0.00	-0.08 -0.08 0.02	-0.19 -0.15 -0.07	0.30 0.23 0.17	0.45 0.46 0.37	0.04 -0.15 -0.15					
CWA	0.24 -0.05 -0.12	-0.03 -0.37 -0.38	0.37 0.41 -0.03	0.06 -0.13 -0.28	-0.28 -0.31 0.02	-0.15 -0.09 -0.04	-0.14 -0.04 -0.02	-0.22 -0.09 -0.07	0.28 0.15 0.13	0.50 0.52 0.39	0.41 0.14 0.20	0.93 0.96 0.94				
LG	-0.09 -0.41 -0.36	0.10 0.58 0.62	0.08 -0.65 -0.47	0.24 -0.10 0.24	0.52 -0.11 0.21	0.50 -0.35 -0.19	0.49 -0.39 -0.22	0.53 -0.34 0.06	-0.51 0.15 -0.40	-0.01 -0.10 0.06	-0.08 -0.12 0.00	-0.06 -0.21 -0.20	-0.09 -0.23 -0.19			
BUL	0.24 0.44 0.47	-0.22 -0.66 -0.57	0.43 0.49 0.28	0.12 -0.06 -0.32	-0.12 0.08 -0.18	-0.12 0.35 0.29	-0.13 0.36 0.31	-0.15 0.27 0.04	0.15 -0.04 0.33	-0.31 -0.06 -0.24	0.03 -0.18 -0.35	-0.03 0.02 0.02	0.00 -0.04 -0.12	-0.14 -0.66 -0.56		
RES	0.03 0.30 0.39	-0.16 -0.52 -0.53	0.01 0.24 -0.05	0.04 -0.06 -0.49	-0.09 0.09 -0.33	-0.17 0.32 0.02	-0.17 0.34 0.04	-0.16 0.22 -0.19	0.11 0.05 0.46	-0.27 -0.23 -0.22	-0.08 -0.17 -0.35	-0.12 -0.04 0.11	-0.12 -0.09 -0.03	-0.15 -0.40 -0.41	0.82 0.84 0.89	

Correlations are arranged in descending order of shearings; 1, 2 and 3 respectively.

For shearings 1 and 2: $r>0.236$ ($p<0.05$), $r>0.307$ ($p<0.01$). For shearing 3 ewes: $r>0.327$ ($p<0.05$), $r>0.419$ ($p<0.01$)

presence of the grease might be confounding with soft handle. On the other hand, Roberts (1956) found that suint was the component of yield that affected handle.

Handle generally tended to become harsher as staple length increased and yield decreased. The magnitude of the correlations, however, was small and inconsistent. Harsh handle also was associated with higher bulk and resilience and lower lustre. Similarly, Ali *et al.* (1971) pointed out that the greater the resistance to compression the harsher is the handle of the wool. It was found that harsh handle and higher medullation index were correlated with increased greasy and clean wool per unit area, probably due to the presence of more continuous medullated fibres which may be coarser and of heavier weight. Doney (1963) showed, in Scottish Blackface, that 50-60% of the among-sheep variation in production per unit area was due to variation in fibre weight, the rest being due to variation in fibre density. The variation in mean fibre weight was further partitioned into 50-70% due to variation in mean cross-sectional area and the remainder to variation in mean fibre length.

1.4.2.3 Medullation index

Medullation index had small correlations with both greasy and scoured colour grades. Among kemp score, handle grade and medullation index, the latter showed higher correlations with tristimulus colour reflectances than the other two subjective assessments. Medullation index is also measured by reflectance so the correlations are not surprising. Correlations of medullation index with X and Y were higher than with Z values. The reflection of the medulla might be absorbed in red (X) and green (Y) spectrums more than in the blue (Z) one. On the other hand, yellowness might cause variation in Z reflectance which reduces the association with medullation index. Nandurkar and Lappage (1977) found that the Y value for yarns correlated reasonably well with medullation index (0.79) and with mean fibre diameter (0.87). Thus the coarse and heavily-medullated fibres dyed lighter than the fine fibres. They indicated that this difference in dyeability leads to differences in shades between fibres of coarse medullated wools, and so to difficulty in achieving solid shades. Ince (1979) also stated that highly-medullated wools appeared to dye to a paler colour than non-medullated wools although they absorb as much dyestuff by weight. This phenomenon is due to internal light reflection in the medullated fibres.

Staple length was positively correlated with medullation index of later fleeces. That trend was sustained by the observations taken from the laboratory which suggested that the continuous medullated fibres are usually the longest fibres in Drysdale fleeces, accounting for the extra staple length. Primary follicles in Drysdales are capable of producing continuously medullated fibres for long periods of time without shedding.

Medullation index was generally associated with lower lustre and higher bulk. Nandurkar and Lappage (1977) found no relation between bulk and medullation index in Drysdale samples.

1.4.2.4 Colour appraisals and measurements

Visual grades of greasy and scoured colour showed correlations ranged between 0.20-0.52. Low phenotypic association between greasy and scoured colour have been reported by Clark and Whiteley (1978), Whiteley *et al.* (1980) and Teasdale (1984). For New Zealand Romney, Chopra (1978) estimated high and positive genetic correlations between GCG and SCG (0.85) indicating the possibility of improving scoured colour grades by selecting for greasy colour grades. When greasy wool is being graded, the colour is often a composite of scourable and non-scourable components. The low phenotypic correlations between GCG and SCG are likely to be due to the presence of scourable colourations and to the variation in grease content (Hoare and Thompson, 1974).

Objective colour measurements had higher correlations with SCG than with GCG. Both greasy and scoured colour assessments had higher correlations with Z (blue) reflectances than with those obtained from either X or Y values. The correlations among X, Y, Z and Y-Z were high, particularly those between X and Y (see also Bigham *et al.*, 1984b). Subjective colour grades as well as tristimulus colour values had negative correlations with Y-Z; the higher the Y-Z value the yellower the wool. The correlations of Y-Z values were generally higher with scoured colour than those with greasy colour. Variations in Y-Z are mainly due to variation in Z value.

Longer staples and higher production per unit area (both greasy and clean) often tended to be correlated with more discoloured wool as indicated by subjective greasy and scoured colour as well as Y-Z. That trend was not clear from tristimulus reflectance values. Working with Coopworth, Romney and Border Leicester, Bigham *et al.* (1983a) showed similar correlations of Y-Z with clean and greasy fleece weights and staple length.

The correlations between yield and greasy colour grades might reflect the quantity and nature of wool-contaminating substances (whether it is scourable or not). Lustre tended to increase as colour improved both subjectively and objectively, particularly in the first shearing. Similarly, bulk and resilience generally tended to increase as colour improved. Bigham *et al.* (1983a) produced negative estimates of the genetic (-0.04) and phenotypic (-0.11) correlations between bulk and Y-Z.

1.4.2.5 Staple length and wool per unit area

Staple length was positively correlated with greasy and clean wool production per unit area particularly when the mean of the positions was the basis. Young and Chapman (1958) suggested that in strong wool breeds staple length contributed the major part towards wool production whereas, in fine wool breeds, density had the greatest influence on wool production.

Shorter staples were correlated with higher bulk and resilience. However, the magnitude of the correlations was small and inconsistent. Similar results were reported elsewhere (Whiteley *et al.*, 1978; Elliott and Carnaby, 1980; Bigham *et al.*, 1983a).

GWA was highly correlated with CWA. Yield appeared far less important as a source of variation in clean production. In both flocks, YLD, GWA and CWA of shoulder samples increased as bulk and resilience decreased. Bigham *et al.* (1983a) reported similar trends.

1.4.2.6 Lustre, bulk and resilience

There were highly positive correlations between bulk and resilience ranging between 0.80 and 0.95. Both bulk and resilience generally showed negative correlations with lustre. A similar trend was reported by Elliott and Carnaby (1980).

Bulk also increased as kemp score, medullation index and harsh handle increased, the correlations being lower for medullation index compared with kemp score and handle.

1.4.2.7 Flock A fleece weight

Table 1.4.31 shows the correlations of first and third fleece weights to various traits at the first shearing on the shoulder and mid-side positions together with the averages of all positions at the first and at the third shearings. Perhaps the most surprising finding was that the correlations were generally so small.

High fleece weight was associated with poor scoured colour as indicated by the correlation with subjective grades and Y-Z. High Y-Z (poor colour) of the first fleece was also associated with higher third fleece weight. These correlations were even higher than that between first and third fleece weight. This latter correlation was surprisingly low and non-significant.

The significant and negative relationship between third fleece weight and average kemp score might indicate that kemp-producing follicles contribute to a lower total weight of fibre output and accordingly reduce the wool production.

At the first shearing, staple length was associated positively and significantly with fleece weight but in the third fleece the association was weak. Rae (1958), Tripathy (1966), Sumner (1969) and Blair (1981) gave correlations of greasy fleece weight and staple length ranging from 0.29 to 0.66 in the New Zealand Romney.

GFW1 increased as yield decreased but there was no significant correlation between yield and greasy third fleece weight. It is not

Table 1.4.31 Correlations of the first and third fleece weights with the first and third shearing traits in Flock A (pooled over sexes).

		KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES	GFW1
GFW1	SH	0.09	0.13	-0.14	0.06	-0.07	0.21	0.22	0.02	0.28	0.59	-0.24	0.49	0.44	0.00	-0.01	-0.07	
	MS	-0.08	-0.19	-0.14	0.09	-0.01	0.20	0.24	0.07	0.21	0.66	-0.28	0.52	0.47	0.28	0.23	0.12	
	AV1	0.17	-0.24	-0.16	-0.09	0.02	0.11	0.12	0.02	0.21	0.64	-0.36	0.59	0.56	0.10	0.04	-0.03	
GFW3	SH	-0.01	0.15	-0.13	0.02	-0.10	0.19	0.20	0.00	0.28	-0.06	0.03	0.23	0.24	0.15	0.06	-0.01	
	MS	0.03	-0.01	-0.19	0.08	-0.04	0.16	0.20	0.06	0.18	0.00	0.06	0.13	0.13	0.29	0.30	0.19	0.17
	AV1	0.17	0.16	-0.08	0.19	0.05	0.17	0.19	0.07	0.24	0.02	0.10	0.21	0.24	0.08	0.25	0.20	
	AV3	-0.30	-0.08	-0.02	-0.06	-0.31	-0.16	-0.14	-0.22	0.28	0.13	0.13	0.48	0.45	0.07	-0.16	-0.09	
CFW3	SH	0.02	0.15	-0.11	-0.05	-0.17	0.13	0.13	-0.08	0.35	-0.10	0.12	0.22	0.25	0.13	0.03	-0.07	
	MS	0.03	-0.04	-0.13	0.04	-0.16	0.13	0.16	0.02	0.23	0.04	0.09	0.06	0.07	0.26	0.26	0.16	0.14
	AV1	0.14	0.16	-0.04	0.15	-0.01	0.13	0.14	0.02	0.28	-0.01	0.20	0.16	0.21	0.05	0.22	0.14	
	AV3	-0.32	-0.10	0.04	0.00	-0.40	-0.12	-0.11	-0.23	0.35	0.17	0.37	0.51	0.59	0.06	-0.25	-0.20	

SH and MS wool samples from the first shearing
AV3 average of wool traits at third shearing
AV1 average of wool traits at first shearing
r>0.271 (p<0.05), r>0.351 (p<0.01).

surprising that there was a positive relationship between average yield in the third shearing and clean third fleece weight since this yield was used in deriving the clean fleece weight.

Fleece weight was reasonably well correlated with wool production per unit area of the same fleece. Wool per unit area measured from shoulder and mid-side samples in the first shearing or the average of all positions was of little value in predicting third fleece weight.

1.4.3 Relations Among Birthcoat Traits

Interrelationships between the proportions of birthcoat fibre types are implicit in the study of arrays (Stephenson, 1952; Elgabbas, 1978); however these interrelations have seldom been analysed statistically.

Tables 1.4.32 and 1.4.33 present least squares means and effects for birthcoat fibre types after transforming back from the arcsine form. Accordingly, the position effects in these tables do not sum to zero.

The array grades were allocated according to the presence or absence of pre-curly tip fibre types; so clearly these grades must be associated with the proportion of certain fibres. Since P3 was the most common array in these data (Table 1.4.34) the proportion of SSB, and more particularly whether SSB fibres were present or not, would be closely related to the array allocated (Table 1.4.35). Since HH fibres were present in all arrays the proportion of which was not closely related to the array, the same might apply for SSA and SSA' fibres. SK fibres were closely related because they would determine whether the array was saddle or not.

Although the correlations between HH and SSA were found to be small and non-significant, the negative sign might indicate that both fibre types are grown from the same follicle; the primary centrals. Fraser *et al.* (1954) stated that primary central follicles produce Pre-CTs while primary laterals produce HTCT and secondaries produce CT and Hi fibres in Drysdale sheep. Wickham (1958) indicated that Pre-CTs can extend into primary lateral follicles or HTCT into primary central follicles and secondaries at times. Presumably this spreading of the HTCT group over more follicles is occurring in lambs with coarser arrays since the latter were found to be associated with a higher proportion of HTCT and fewer Pre-CT and CT fibres (Table 1.4.35). The relation between coarser arrays and a higher proportion of HTCT fibres was also indicated by Stephenson (1952).

Since HH, SSA, SSA' and SSB are all components of the Pre-CT group of fibres it is not surprising from statistical considerations

Table 1.4.32 Least squares means and effects for birthcoat fibre types in Flock A.

	HH	SSA	SSA'	SSB	SS	SK	Pre.CT	HTCT1	HTCT2	HTCT	CT1	CT2	CT
Mean	8.54	3.95	1.63	6.10	13.46	0.68	23.73	15.93	8.44	29.95	0.09	44.75	43.35
Sex													
Male	0.00	0.00	0.00	0.00	0.00	0.00	+0.01	0.00	+0.10	+0.05	0.00	-0.14	-0.11
Birth rank													
Single	0.00	0.00	0.00	-0.04	-0.05	0.00	-0.03	+0.03	+0.10	+0.11	-0.07	0.00	-0.02
Dam age													
2-yr	0.00	0.00	0.00	+0.08	+0.05	0.00	+0.05	0.00	-0.10	-0.03	+0.01	0.00	0.00
Position													
SH	-0.04	+0.03	-0.09	-0.21	-0.13	0.00	-0.21	-0.03	+0.08	0.00	0.00	+0.23	+0.18
MS	-0.06	0.00	-0.02	-0.08	-0.13	0.00	-0.25	+0.18	-0.07	+0.05	0.00	+0.13	+0.12
BR	0.00	+0.39	+0.02	-0.12	+0.09	0.00	+0.03	+0.49	-0.13	+0.15	0.00	-0.12	-0.13
WH	-0.03	-0.70	-0.03	-0.42	-1.50	-0.02	-1.25	+0.40	+0.08	+0.09	0.00	+0.11	+0.14
BK	+0.02	0.00	0.00	-0.42	-0.15	-0.03	-0.09	+0.27	+0.45	+0.74	0.00	-0.24	-0.18
RP	+0.04	-0.04	0.00	-0.06	-0.08	-0.03	-0.03	+0.37	+0.38	+0.86	-0.03	-0.19	-0.29
SP	+0.15	+0.01	0.00	+1.47	+1.19	+0.16	+1.68	-2.96	-0.71	-4.60	+0.01	+0.04	+0.07
BL	0.00	0.00	+0.22	+1.88	+1.49	+0.04	+1.11	-0.97	-0.13	-0.99	0.00	-0.01	0.00
Birth date	-0.01	+0.14	+0.02	-0.13	+0.03	0.00	+0.01	-0.21	+0.10	-0.17	+0.13	+0.02	+0.11

The female, twin and older dam effects have the same magnitude as, but opposite sign to, the male, single and 2-yr dam effects.
Based on analysis in the arcsine form but detransformed.

Table 1.4.33 Least squares means and effects for birthcoat fibre types in both flocks

	HH	SSA	SSA'	SSB	SS	SK	Pre-CT	HTCT1	HTCT2	HTCT	CT1	CT2	CT
Mean	8.50	3.32	1.15	3.45	8.94	0.38	18.34	27.26	4.21	34.92	1.76	40.36	45.40
Flock													
A	-0.04	+0.17	+0.07	0.00	+0.24	0.00	+0.08	+0.94	-0.22	+0.05	+0.15	-0.53	-0.23
Sex													
Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.10	+0.16	0.00	-0.03	0.00	-0.01
Birth rank													
Single	0.00	0.00	0.00	-0.03	-0.04	0.00	-0.03	0.00	+0.04	+0.03	-0.02	0.00	0.00
Dam age													
2-yr	0.00	0.00	0.00	+0.10	+0.03	0.00	+0.01	0.00	-0.11	-0.07	+0.02	0.00	+0.02
Position													
SH	-0.13	+0.04	0.00	+0.03	+0.04	+0.01	0.00	-1.06	-0.15	-1.25	-0.01	+1.21	+1.00
MS	-0.17	0.00	0.00	+0.10	+0.02	+0.01	-0.03	-0.18	-0.29	-0.43	0.00	+0.54	+0.51
BR	-0.03	+0.35	+0.04	+0.04	+0.50	0.00	+0.20	0.00	-0.45	-0.19	-0.01	+0.02	0.00
BK	+0.91	-0.59	0.00	-0.46	-1.05	-0.06	-0.04	+2.19	+2.53	+4.80	+0.05	-3.95	-3.13
Birth date	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Flock B, female, twin and older dam effects have the same magnitude as, but opposite sign to, the Flock A, male, single and 2-yr dam effects

Based on analysis in the arcsine form but detransformed

Table 1.4.34 Percentages of fibre type arrays according to position and flock

Flock	Array	SH	MS	BR	WH	BK	RP	SP	BL
	P0	-	-	-	4.2	-	-	-	-
	P1	5.6	6.9	5.6	4.2	12.5	-	1.4	1.4
A	P2	11.1	6.9	16.7	19.4	13.9	19.4	1.4	1.4
	P3	76.3	80.6	70.8	70.8	73.6	80.6	72.2	81.9
	saddle	7.0	5.6	6.9	1.4	-	-	25.0	15.3
	P0	-	-	-		-			
	P1	9.7	8.3	6.9		9.7			
B	P2	14.0	4.2	19.4		11.1			
	P3	69.4	80.6	73.6		77.8			
	saddle	6.9	6.9	-		1.4			

Table 1.4.35 Correlations between shoulder and mid-side birthcoat traits (pooled over sexes and flocks).

	ARY	HH	SSA	SSA'	SSB	SS	SK	Pre.CT	HTCT1	HTCT2	HTCT	CT1	CT2	CT
ARY														
HH	-0.03 0.02													
SSA	-0.03 -0.18	-0.11 -0.03												
SSA'	0.16 0.17	0.13 0.08	0.06 0.16											
SSB	0.52 0.51	0.08 0.02	-0.16 -0.21	0.26 0.20										
SS	0.32 0.20	0.03 0.01	0.65 0.65	0.43 0.49	0.62 0.54									
SK	0.51 0.44	-0.05 -0.14	-0.10 -0.17	0.05 0.04	0.27 0.15	0.12 -0.03								
Pre.CT	0.31 0.25	0.47 0.48	0.52 0.50	0.42 0.49	0.60 0.52	0.91 0.87	0.20 0.09							
HTCT1	-0.34 -0.31	-0.05 0.12	0.02 0.11	-0.16 0.00	-0.39 -0.24	-0.23 -0.10	-0.31 -0.43	-0.25 -0.09						
HTCT2	-0.17 -0.13	0.05 -0.03	-0.08 0.06	-0.18 -0.09	-0.12 -0.10	-0.20 -0.01	-0.13 -0.15	-0.18 -0.04	-0.28 -0.33					
HTCT	-0.42 -0.36	-0.01 0.10	-0.06 0.16	-0.24 -0.05	-0.42 -0.24	-0.35 -0.05	-0.44 -0.56	-0.36 -0.08	0.54 0.60	0.66 0.57				
CT1	0.33 0.38	-0.12 -0.21	-0.16 -0.23	0.01 0.06	0.23 0.13	0.04 -0.10	0.52 0.59	0.07 0.20	-0.34 -0.37	-0.27 -0.24	-0.53 -0.56			
CT2	0.01 -0.09	-0.14 -0.12	-0.07 -0.18	-0.01 -0.23	-0.11 -0.10	-0.14 -0.26	-0.07 -0.04	-0.21 -0.31	-0.19 -0.24	-0.45 -0.41	-0.52 -0.54	-0.30 -0.27		
CT	0.24 0.21	-0.19 -0.26	-0.24 -0.35	0.00 -0.18	0.07 -0.01	-0.13 -0.35	0.26 0.37	-0.18 -0.38	-0.39 -0.48	-0.58 -0.55	-0.85 -0.89	0.45 0.46	0.79 0.74	

Correlations are arranged in descending order of positions SH and MS respectively.
$r>0.236$ ($p<0.05$), $r>0.307$ ($p<0.01$).

that the proportion of each was associated with a high proportion of total Pre-CT fibres. However, the proportion of SK fibres was only weakly correlated with Pre-CTs, probably because SK fibres were present in so few samples.

High proportions of SSB and SK fibres were associated with low proportions of HTCT, particularly coarser HTCT fibres (HTCT1). More SK fibres were found to be associated with more CTs, presumably because follicles destined to produce fibres with curly-tips did not have the same tendency to produce medulla cells.

1.4.4 Birthcoat-Adult Fleece Relationships

Perhaps the outstanding point in Tables 1.4.36 and 1.4.37 is that the birthcoat traits are only poorly related to fleece traits in Drysdales. This indicates that birthcoat traits are inefficient as an aid to early selection for various fleece traits. Partly this is a reflection of the uniformity of the birthcoat and of the adult fleeces in these sheep. If the flock had been part-Drysdale and part-Romney in origin and therefore like the genotypes that Dry worked with in his early days, the correlations would probably be far stronger.

Kemp score surprisingly was negatively correlated with the proportion of HHs in Flock A and positively associated with the proportion of SK fibres. This may be because kemps are more visible when the other fibres in the fleece are fine. In kemp succession studies it has been shown that HH fibres are frequently succeeded by kemps (Ross and Wright, 1954; Guirgis, 1967; Elgabbas, 1978; Guirgis *et al.*, 1979a, b) and it has been suggested that having more SK fibres would lead to fewer kemps.

In Flock A, handle was reasonably independent of the fibre types but in Flock B softness was associated with more SSB and CT fibres as well as fewer SSA and HTCT1 fibres.

High medullation index, as expected, was correlated with coarser arrays particularly in Flock B in which medullation index tended to increase as SSA and HTCT fibres increased and SSB and CT fibres decreased. Similar results were obtained by Stephenson (1956).

Colour measurements were associated loosely with birthcoat traits probably through increased reflectance from more medullated wool.

In Flock A staple length was negatively associated with the proportion of HTCT2 fibres, probably growing in early secondary follicles; an explanation for this is difficult to find. No explanation has been found for the tendency of fine arrays to be associated with higher clean scoured yield.

In Flock A clean and greasy production per unit area and fleece weight were positively correlated to the proportion of HH fibres.

Table 1.4.36 Correlations between averages of third shearing traits and birthcoat traits taken from SH and MS positions in Flock A (pooled over sexes).

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES	GFW1	GFW3	CFW3
ARY	-0.08	-0.02	-0.20	0.05	-0.26	-0.11	-0.12	-0.18	0.18	-0.04	0.26	0.17	0.23	0.27	-0.29	-0.24	-0.02	-0.02	0.04
	0.00	-0.13	-0.07	-0.01	-0.14	-0.21	-0.22	-0.10	0.09	0.20	0.24	0.18	0.24	0.17	-0.25	-0.26	-0.04	-0.11	-0.05
HH	-0.39	0.15	0.15	-0.04	-0.19	-0.06	-0.06	-0.10	0.05	0.03	-0.14	0.25	0.17	-0.04	-0.04	-0.03	0.18	0.20	0.09
	-0.38	0.14	0.15	0.03	-0.34	-0.09	-0.09	-0.21	0.32	-0.01	0.15	0.33	0.30	-0.07	-0.09	-0.08	0.30	0.32	0.33
SSA	-0.03	0.02	0.24	0.06	0.06	0.23	0.22	0.19	-0.13	0.18	0.17	-0.10	-0.04	-0.07	-0.08	-0.14	-0.31	-0.04	-0.01
	-0.27	0.07	0.22	-0.18	-0.09	-0.05	-0.06	-0.09	0.09	0.00	-0.09	-0.06	0.00	0.03	-0.10	-0.08	-0.10	-0.04	-0.08
SSA'	-0.12	-0.17	0.29	0.17	0.14	0.29	0.28	0.24	-0.12	0.19	-0.01	-0.08	0.05	-0.22	0.06	-0.02	-0.06	0.05	0.04
	-0.02	-0.39	0.26	0.02	-0.11	0.09	0.08	0.01	0.06	0.13	0.12	0.01	0.03	-0.04	-0.18	-0.23	-0.18	0.05	0.07
SSB	-0.02	0.07	0.06	0.12	-0.07	0.17	0.16	0.13	-0.05	0.23	0.23	0.11	0.15	-0.02	-0.37	-0.30	-0.23	-0.09	-0.04
	-0.18	0.17	-0.01	0.08	-0.11	-0.12	-0.14	-0.08	-0.02	0.29	0.16	-0.05	0.07	0.04	-0.17	-0.20	-0.16	-0.20	-0.15
SS	-0.08	-0.03	0.25	0.14	-0.03	0.28	0.27	0.41	-0.10	0.30	0.24	0.02	0.09	-0.10	-0.17	-0.26	-0.32	-0.03	0.02
	-0.31	0.02	0.25	-0.09	-0.21	-0.07	-0.09	-0.13	0.13	0.24	0.01	0.09	0.08	0.02	-0.24	-0.25	-0.25	-0.07	-0.07
SK	0.20	-0.32	-0.11	0.00	-0.15	-0.01	0.00	-0.11	0.19	-0.12	0.25	-0.08	0.02	0.06	0.02	0.05	-0.04	-0.08	-0.03
	0.26	-0.15	-0.15	-0.08	0.05	-0.01	-0.02	0.03	-0.07	-0.06	0.16	-0.01	0.03	0.14	0.01	0.05	-0.15	-0.14	-0.10
Pre.CT	-0.17	0.05	0.25	0.14	-0.06	0.24	0.24	0.17	-0.06	0.26	0.15	0.08	0.11	-0.09	-0.15	-0.22	-0.23	0.02	0.04
	-0.35	0.06	0.24	-0.06	-0.28	-0.10	-0.12	-0.18	0.20	0.20	0.08	0.17	0.16	0.02	-0.23	-0.24	-0.13	0.02	0.03
HTCT1	-0.26	-0.03	0.18	0.00	-0.08	0.10	0.11	0.02	0.13	-0.07	0.02	-0.13	-0.10	-0.20	0.08	0.03	0.38	0.06	0.08
	-0.34	-0.04	0.21	-0.03	-0.19	0.02	0.03	-0.10	0.24	0.16	0.04	0.06	0.08	-0.23	-0.08	-0.11	0.21	0.09	0.11
HTCT2	0.04	0.08	-0.18	0.04	0.08	-0.01	-0.02	-0.03	0.04	-0.36	-0.03	0.06	0.05	-0.03	0.09	0.05	0.31	0.05	0.05
	0.04	-0.04	0.04	0.09	0.09	0.16	0.16	0.09	0.03	-0.24	0.11	0.04	0.09	-0.02	0.05	-0.01	0.28	0.07	0.11
HTCT	-0.14	0.06	0.01	-0.07	0.02	0.07	0.07	0.01	0.08	-0.30	-0.01	-0.02	-0.01	-0.10	0.08	0.04	0.46	0.05	0.07
	-0.28	-0.03	0.19	0.06	-0.09	0.15	0.15	0.01	0.19	-0.04	0.13	0.09	0.14	-0.13	-0.07	-0.14	0.33	0.11	0.15
CT1	0.42	-0.11	-0.21	0.11	0.12	-0.05	-0.05	0.05	-0.16	0.00	0.08	-0.01	0.00	0.20	0.03	0.10	-0.37	-0.15	-0.13
	0.46	-0.18	-0.23	-0.10	0.13	-0.10	-0.10	0.02	-0.17	-0.01	0.05	-0.01	-0.01	0.18	0.03	0.12	-0.37	-0.16	-0.14
CT2	-0.02	0.00	-0.02	-0.18	-0.09	-0.24	-0.23	-0.18	0.06	0.23	-0.14	0.04	-0.01	0.12	-0.07	0.02	-0.21	0.03	-0.02
	0.11	0.17	-0.24	-0.03	0.14	-0.10	-0.09	0.03	-0.18	-0.04	-0.29	-0.16	-0.24	0.04	0.17	0.19	-0.02	0.02	-0.07
CT	0.17	-0.05	-0.09	-0.18	-0.02	-0.24	-0.23	-0.14	-0.02	0.20	-0.09	0.02	-0.03	0.17	-0.04	0.06	-0.34	-0.05	-0.08
	0.39	0.02	-0.33	-0.08	0.23	-0.13	-0.13	0.05	-0.26	-0.04	-0.22	-0.15	-0.22	0.14	0.17	0.24	-0.24	-0.09	-0.15

Correlations are arranged in descending order of positions SH and MS respectively. $r>0.236$ ($p<0.05$), $r>0.307$ ($p<0.01$).

Table 1.4.37 Correlations between averages of the third shearing traits and birthcoat traits taken from SH and MS positions in Flock B ewes.

	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
ARY	-0.05	0.29	-0.55	0.11	0.04	-0.33	-0.33	-0.24	0.06	-0.15	0.01	-0.14	-0.14	0.27	-0.22	-0.01
	-0.13	0.15	-0.36	0.08	0.08	-0.25	-0.25	-0.17	0.03	0.27	0.38	0.06	0.20	0.12	-0.25	-0.10
HH	0.11	0.18	0.13	0.12	0.16	0.16	0.16	0.16	-0.11	-0.13	0.11	-0.25	-0.20	-0.02	0.02	-0.03
	0.11	0.10	-0.05	-0.11	-0.08	-0.26	-0.26	-0.24	0.16	-0.15	0.12	-0.10	-0.06	-0.07	-0.09	-0.04
SSA	0.24	-0.40	0.41	0.13	0.15	0.52	0.53	0.41	-0.16	0.12	-0.01	0.18	0.17	-0.26	0.28	0.10
	0.15	-0.25	0.41	-0.02	0.16	0.30	0.30	0.27	-0.17	0.02	-0.03	0.09	0.07	-0.33	0.15	-0.05
SSA'	0.24	-0.27	-0.13	0.00	0.10	0.20	0.21	0.13	-0.01	-0.01	0.03	0.16	0.18	-0.03	0.23	0.30
	0.05	-0.17	-0.07	0.09	-0.19	0.00	0.00	-0.12	0.26	-0.22	-0.10	-0.26	-0.28	-0.23	0.33	0.32
SSB	-0.03	0.38	-0.36	0.20	0.09	-0.23	-0.24	-0.09	-0.12	-0.04	0.08	-0.25	-0.23	0.28	-0.28	-0.17
	-0.29	0.29	-0.43	0.25	0.11	-0.23	-0.23	-0.10	-0.10	0.26	0.30	0.00	0.11	0.28	-0.32	-0.18
SS	0.27	-0.09	0.04	0.33	0.26	0.37	0.37	0.36	-0.26	0.06	0.11	-0.03	0.01	-0.03	0.14	0.06
	-0.10	0.02	0.01	0.24	0.19	0.07	0.07	0.12	-0.16	0.13	0.21	-0.03	0.04	-0.16	-0.01	-0.10
SK	0.06	0.31	-0.30	0.15	-0.01	-0.14	-0.14	-0.11	0.05	-0.24	0.23	-0.18	-0.10	0.10	-0.07	0.00
	0.02	0.12	-0.10	0.12	0.01	-0.09	-0.09	-0.07	0.04	-0.05	0.26	-0.05	0.04	0.03	-0.19	-0.15
Pre.CT	0.32	0.00	0.08	0.37	0.30	0.40	0.40	0.39	-0.29	0.00	0.19	-0.18	-0.11	-0.05	0.16	0.06
	-0.04	0.08	-0.05	0.23	0.13	-0.11	-0.11	-0.06	-0.03	0.02	0.37	-0.11	0.01	-0.19	-0.12	-0.17
HTCT1	-0.13	-0.43	0.40	-0.02	-0.15	0.21	0.22	0.07	0.13	0.16	-0.24	0.18	0.11	-0.26	0.18	0.12
	0.17	-0.30	0.07	-0.18	-0.28	-0.14	-0.14	-0.17	0.17	0.02	-0.14	0.14	0.09	-0.08	0.07	0.16
HTCT2	0.12	0.02	0.28	-0.04	0.19	0.13	0.14	0.08	0.01	-0.18	-0.06	0.07	0.03	-0.16	0.12	-0.03
	0.08	-0.08	0.40	0.12	0.33	0.35	0.35	0.26	-0.08	-0.09	-0.23	0.14	0.05	-0.36	0.29	0.04
HTCT	-0.13	-0.39	0.50	-0.10	-0.04	0.21	0.22	0.07	0.16	0.04	-0.30	0.25	0.15	-0.28	0.20	0.07
	-0.10	-0.30	0.32	-0.09	-0.05	0.10	0.10	0.02	0.09	-0.03	-0.29	0.21	0.11	-0.26	0.21	0.14
CT1	-0.13	0.21	-0.18	0.08	0.08	-0.23	-0.24	-0.06	-0.19	0.25	0.04	-0.07	-0.05	0.23	-0.36	-0.24
	-0.03	0.04	-0.02	-0.02	0.07	0.02	0.02	0.08	-0.15	0.29	-0.04	-0.01	-0.02	0.27	-0.18	-0.11
CT2	0.09	0.17	-0.35	-0.11	-0.16	-0.13	-0.13	-0.16	0.16	-0.30	0.18	-0.10	-0.04	0.09	0.09	0.14
	0.15	0.20	-0.24	-0.05	-0.02	-0.05	-0.05	-0.06	0.06	-0.24	0.22	-0.07	0.00	0.01	0.04	0.03
CT	-0.05	0.40	-0.58	-0.07	-0.11	-0.42	-0.44	-0.26	-0.03	-0.03	0.21	-0.18	-0.11	0.36	-0.31	-0.12
	0.11	0.25	-0.29	0.00	0.00	-0.05	-0.05	0.01	-0.08	0.02	0.15	-0.14	-0.09	0.31	-0.15	-0.07

Correlations are arranged in descending order of positions SH and MS respectively.
$r>0.327$ ($p<0.05$), $r>0.419$ ($p<0.01$).

Since HHs are the most vigorously-growing fibres in the birthcoat, their presence may be indicative of general wool-producing ability. On the other hand, higher GFW1 has been found to be associated with higher proportion of HTCT fibres and fewer CT1 fibres.

More bulky and resilient fleeces were produced by sheep which had coarser birthcoat arrays and which had fewer SSB fibres.

1.4.5 Predicting Some Third Fleece Traits From Lamb Traits Using Multiple Regression Analysis

A multiple regression study was conducted in order to select optimal combinations of first shearing and birthcoat traits to predict the average medullation index, bulk and fleece weights in the third shearing. These models were obtained from different body positions and are presented in Tables 1.4.38 to 1.4.41. The best models were chosen on the basis of adjusted R^2 (hereafter referred to as R^2). Models of medullation index and bulk were made within flock-sex groups (both sexes in Flock A and Flock B ewes), while models of the third fleece weight were presented for each sex in Flock A. In all positions, flock-sex groups accounted for 26% and 11% to the total variation in the third fleece medullation index and bulk respectively. Prediction equations were chosen partly on the basis of their reliability and partly on the basis of the cost and technical difficulty of collection of data on independent variables.

1.4.5.1 Predicting third fleece medullation index

The best data to predict medullation index of the third shearing (MI3) were obtained from back (BK1) and shoulder (SH1) positions in the first shearing (Table 1.4.38). Measurements of medullation index in the first fleece were the major factor in predicting the corresponding value in the third fleece. Fitting first shearing medullation index within flock-sex groups gave R^2 values of 49% (shoulder), 49% (back), 40% (mid-side) and 35% (britch).

Addition of kemp score (from shoulder) and handle grade (from back) to medullation index in the model appeared useful despite the small R^2 values obtained when KS (28%) and HG (25%) were fitted separately within flock-sex groups. Thus the regression equations which were most useful in predicting MI3 were

$$\text{MI3} = 9.15 + 0.45\ \text{MI (SH1)} + 1.84\ \text{KS (SH1)}$$

$$\text{or}\quad \text{MI3} = 9.35 + 0.49\ \text{MI (BK1)} + 1.20\ \text{HG (BK1)}.$$

Table 1.4.38 Multiple regression models to predict *third shearing medullation index* from lamb traits within flock-sex groups.

Position		Optimal Models	Adjusted R^2
Shoulder	1	$14.55 + 0.44\ MI - 5.05\ SSA_p + 1.93\ KS$	0.54
	2	$16.44 + 0.44\ MI - 5.07\ SSA_p + 0.16\ HH\%$	0.52
	3	$18.21 + 0.45\ MI - 4.82\ SSA_p$	0.52
	4	$9.15 + 0.45\ MI + 1.84\ KS$	0.51
Mid-side	1	$9.07 + 0.33\ MI + 3.06\ SSB_p + 0.16\ SS\%$	0.46
	2	$16.20 + 0.34\ MI + 2.67\ SSB_p - 0.33\ STL$	0.45
	3	$11.93 + 0.34\ MI + 2.78\ SSB_p$	0.44
Britch	1	$6.53 + 0.26\ MI + 2.88\ SSB_p + 0.24\ Pre\text{-}CT\%$	0.42
	2	$8.34 + 0.26\ MI + 2.86\ SSB_p + 0.22\ SS\%$	0.41
Back	1	$6.35 + 0.48\ MI + 2.82\ SSB_p + 0.19\ SS\%$	0.56
	2	$6.34 + 0.49\ MI + 2.20\ SSB_p + 1.22\ HG$	0.54
	3	$11.10 + 0.46\ MI + 2.18\ SSB_p$	0.52
	4	$9.35 + 0.49\ MI + 1.20\ HG$	0.50

SSA_p presence of SSA

SSB_p presence of SSB

Table 1.4.39 Multiple regression models to predict *third shearing bulk* from lamb traits within flock-sex groups.

Position		Optimal Models	Adjusted R^2
Shoulder	1	4.13 - 0.46 HG + 0.48 RES + 0.24 X	0.30
Mid-side	1	9.10 + 0.40 BUL + 0.70 KS + 0.13 STL	0.31
	2	10.72 + 0.40 BUL + 0.76 KS	0.30
Britch	1	14.77 + 0.28 BUL - 0.57 HG + 0.53 KS	0.28
	2	15.47 + 0.29 BUL - 0.74 HG + 0.31 GCG	0.28
Back	1	11.90 - 1.01 HG + 0.59 Y - 0.41 Z	0.28
	2	16.62 - 0.73 HG + 0.23 BUL + 0.16 STL	0.27

1.4.5.2 Predicting third fleece bulk

All models to predict bulk in the third shearing were inefficient (Table 1.4.39). First fleece bulk, within flock-sex groups, controlled most of the variation in the third fleece bulk on MS (26%), BR (20%) and BK (21%) positions. In Flock A, bulk of the third fleece had correlations of only 0.35 and 0.29 with the first fleece bulk on shoulder and mid-side positions. The corresponding values were 0.22 and 0.63 in Flock B (see Appendix 2, Tables A5 and A6).

1.4.5.3 Predicting fleece weights (GFW3 and CFW3)

Models based on shoulder (for rams) and back data (for ewes) gave the best prediction for GFW3 and CFW3. Models based on other positions had lower R^2 values particularly in ewes.

Table 1.4.40 shows the model including HH% together with X and Z reflectances which best predicted GFW3 and CFW3 in the ram data. Fitting the percentage of HH fibres alone gave R^2 values of 19% (GFW3) and 11% (CFW3). Heavier fleece weight and higher HH% may both reflect more vigorously-growing follicles.

Fitting X, Z or GFW1 separately gave negligible control of GFW3 and CFW3 (R^2 0%-4%), but fitting X and Z together accounted for more variation (R^2 in GFW3 25% and in CFW3 32%). Omitting GFW1 from the model had no effect on R^2 and when it was included the partial regression coefficient was negative. GFW1 showed correlations of 0.05 and 0.27 with GFW3 in ewes and rams respectively. The corresponding values for CFW3 were 0.03 and 0.24.

The positive partial regression of fleece weight on X value indicates an association with brightness. The negative partial regression on Z value suggests that heavier fleece weight is associated with yellower scoured wool on the shoulder position. On the other hand Table 1.4.41 indicates that heavier fleece weight is associated with higher GCG (whiter wool) on the back position. These conflicting results in the different situations defy rational explanation.

Table 1.4.40 Multiple regression models to predict GFW3 and CFW3 from *shoulder* lamb traits within Flock A *rams*.

	Optimal Models	Adjusted R^2
GFW3	-1.47 + 0.04 HH% + 0.14 X - 0.09 Z	0.49
	-1.87 + 0.05 HH% + 0.16 X - 0.10 Z - 0.15 GFW1	0.49
CFW3	-1.91 + 0.04 HH% + 0.15 X - 0.10 Z - 0.14 GFW1	0.49
	-1.53 + 0.03 HH% + 0.14 X - 0.09 Z	0.49

Table 1.4.41 Multiple regression models to predict GFW3 and CFW3 from *back* lamb traits within Flock A *ewes*.

	Optimal Models	Adjusted R^2
GFW3	-4.70 + 0.22 BUL + 0.22 HG + 0.53 GCG - 0.02 MI	0.46
	-7.09 + 0.20 BUL + 0.56 GCG - 0.02 MI + 0.04 YLD	0.46
	-4.60 + 0.20 BUL + 0.20 HG + 0.50 GCG	0.45
CFW3	-6.43 + 0.15 BUL + 0.52 GCG - 0.02 MI + 0.04 YLD	0.49
	-5.72 + 0.13 BUL + 0.50 GCG + 0.03 YLD	0.46
	-3.70 + 0.15 BUL + 0.51 GCG + 0.16 HG - 0.01 MI	0.44
	-3.63 + 0.14 BUL + 0.49 GCG + 0.14 HG	0.44

The model including bulk as well as subjective estimates of handle and greasy colour seems the most convenient to predict GFW3 and CFW3 in ewe data (Table 1.4.41) despite the R^2 value being slightly less than the highest R^2 values obtained. The slight improvement in R^2 resulting from including MI and YL would not pay for the extra work and cost involved in estimating these traits.

Fitting first fleece bulk alone accounted for 28% and 19% of the variation in GFW3 and CFW3. First fleece bulk had higher correlations with GFW3 and CFW3 in ewes (0.55, 0.47) than in rams (0.12, 0.10). The corresponding values for greasy colour grades were 0.28 and 0.38 in ewes and 0.01 and -0.01 in rams. Heavier fleece weight was found to be associated with higher bulk, lower MI and softer handle.

It is difficult to justify the inclusion of the factors in these models biologically and this suggests that the choice of these models may be due largely to chance associations.

1.5 CONCLUSIONS

Birthcoat traits were poorly correlated with the third fleece traits which was probably due to the uniformity of the birthcoat and the adult fleece in these sheep. This implies that birthcoat traits are not efficient in predicting later fleece traits.

Phenotypic correlations among fleece traits were estimated from shoulder and mid-side positions as well as among fleece averages calculated from all positions. These were derived within each of two flocks and within each of the three shearings. On the basis of fleece averages, KS was positively correlated with BUL (0.24 to 0.64), RES (0.03 to 0.48) and tristimulus colour values (0.08 to 0.46). Softer handle grade (HG) was associated with lower BUL (-0.22 to -0.66) and RES (-0.16 to -0.53) and higher LG (0.10 to 0.62). Higher MI was generally correlated with higher BUL (-0.15 to 0.49) and tristimulus colour values (-0.01 to 0.60) and lower LG (-0.65 to 0.08). The correlations of tristimulus colour values were higher with scoured colour grade (0.52 to 0.92) than with greasy colour grade; GCG (0.32 to 0.55). Correlations among tristimulus colour values were generally high, particularly between X and Y reflectances (0.93 to 1.00). The correlations of Y-Z were the highest with Z reflectance (-0.67 to -0.92). Greasy and clean wool per unit area (GWA and CWA) were highly correlated (0.93 to 0.96). GFW1 showed a correlation of 0.59 with GWA and of 0.56 with CWA. Longer STL was associated with higher GWA (0.37 to 0.60), CWA (0.39 to 0.60) and GFW1 (0.64) and with lower BUL (-0.01 to -0.54). BUL and RES were highly correlated (0.82 to 0.95). LG was negatively correlated with BUL (-0.12 to -0.66) and RES (-0.10 to -0.41).

Position was generally the main source of variation for all traits studied. Posterior positions had more medullated, kempier and harsher handling wool with higher bulk (BUL) and resilience (RES). Generally, dorsal positions produce more wool with higher kemp score (KS), BUL, RES and harsher handle while lateral positions had whiter wool with higher medullation index (MI) and lustre (LG).

Overall, sex, birth rank and age of dam made little contribution to the total variation in most traits studied. However, rams had heavier third fleece weights. Singles produced heavier first greasy fleece weight (GFW1) with higher BUL and RES than twins. The offspring of older dams had higher LG and softer wool.

Shearing and flock effects were important sources of variation in many traits. In all traits, the ranking of positions was not consistent among shearings. Sire effects were also important in KS, MI, BUL, RES and staple length (STL). The ranking of sires differed among shearings and between sexes in many traits. Sire X birth rank interaction was found to be significant for several traits; such interactions should be studied in larger sets of data since they could have important implications for genetic improvement plans.

Plateau (P3) was the most common array in Drysdale samples; sickle fibres were present in few samples. Coarser arrays were associated with higher proportion of hairy-tip curly-tip fibres (HTCT) and fewer pre-curly tip (Pre-CT) and coarser curly-tip (CT1) fibres. GFW1 increased as HTCT fibres increased (0.33 to 0.46) and CT1 fibres decreased (-0.37). Birthcoat traits were not strongly correlated with the third fleece traits. High MI was associated with coarser arrays (-0.07 to -0.55) and higher proportions of super-sickle A fibres (0.22 to 0.41). Finer arrays were associated with higher yield (0.01 to 0.38). In one flock, sheep with a higher proportion of halo-hair fibres (HH) had higher GWA (0.25 to 0.33), CWA (0.17 to 0.30) and heavier third fleece weights (0.09 to 0.33). BUL was associated with coarser birthcoat arrays (-0.22 to -0.29) and fewer super-sickle B fibres (-0.17 to -0.37).

CHAPTER 2

STUDY OF THE SAMPLING POSITIONS IN DRYSDALE SHEEP

2.1 INTRODUCTION

Analysing whole fleeces for various wool traits is time-consuming, costly and usually impossible on a laboratory scale particularly where large numbers of animals are involved. Considering the variation within a fleece, it is of paramount importance to decide the best position or positions from which to obtain samples for testing.

A number of investigators have studied this point. In Rambouillets (Schott *et al.*, 1942; Pohle *et al.*, 1943), Merino (Doney, 1959; Thornberry and Atkins, 1984) and Navajo and cross-bred sheep (Grandstaff, 1942) it was found that clean yield of shoulder or shoulder and mid-side positions gave an accurate estimate of the clean yield of the whole fleece. In Merinos, the most reliable positions for staple length, crimp per inch and yield appeared to be along shoulder - mid-side - and hip regions (Lockart, 1954). Doney (1959) indicated that the mid-side position gave good estimates of overall mean staple and fibre lengths. While proposing the mid-side position as a representative for fibre length and diameter estimations, Young and Chapman (1958) reported that back and shoulder positions have staple lengths similar to the mean of all positions. Also the upper shoulder wool gave estimates slightly closer to the mean fibre length and diameter. Chapman and Young (1957) showed that shoulder, mid-side and thigh are suitable sampling positions for the measurements of wool production. In Indian breeds, Acharya *et al.* (1972) found that the back position is the best indicator for fibre diameter, fibre length and medullation percentages. Sumner and Revfeim (1973) accepted the mid-side position to be representative to the mean fibre diameter in New Zealand Romney fleeces. Also, Bigham *et al.* (1984a, b) stated that mid-side is a suitable sampling position for loose wool bulk and colour measurements in New Zealand Romney, Coopworth and Perendale sheep. In Australian Merinos, Turner *et al.*, (1953, cited by Turner, 1956) recommended the mid-side position for "general purpose" sampling.

All previous workers defined the best sampling position as that one which has a high correlation with overall fleece mean and/or gives an actual value close to that mean. To calculate the overall fleece mean some workers used the average of all fixed positions while others used a randomly-drawn composite sample on the other side of the sheep. Using the average from random samples can avoid bias and misrepresentation of the population since random samples give every item in the population an equal chance to be selected and measured.

Choosing the best sampling position is of some importance in sheep breeding programmes. In the present study the definition of the best sampling position was not simply that it should be representative of the whole fleece. The genetic contribution to variation of traits on various positions should be emphasised since the selection will be based on these assessments of the traits. The phenotypic variation at various positions should also be considered. The ability of such a position to aid in early selection would be of advantage.

Accordingly, the best sampling position can be judged in terms of six criteria. It should have:

1. high correlations with overall fleece means calculated from randomly-chosen positions;
2. high correlations with overall fleece mean calculated from fixed positions;
3. actual value close to the overall fleece mean;
4. high genetic contribution (sire variance ratio or heritability);
5. high phenotypic variation;
6. high utility in predicting later fleece traits.

While there is a little information available on the first three criteria there is no published information on the last three. In the present material it was not possible to estimate the heritability or genetic correlations due to the number of sires involved (5 sires in Flock A and 9 sires in Flock B). However, sire variance ratios akin to the heritability were estimated. The present study was initiated to examine these six criteria with various wool traits in order to help reach an overall decision as to the best sampling position to be used for breeding purposes.

2.2 MATERIALS AND METHODS

2.2.1 Random Positions Study

Ten N^dN^d ewe lambs were chosen at random from the Massey University Drysdale flock during the lambing season in September 1981. These animals were used to provide wool samples at three shearings in December 1981, April 1982 and October 1982. The number was reduced to 8 sheep in both second and third shearings. These animals were run with Flock A, the management of which was described in Chapter 1.

The day before shearing, wool samples were collected using Oster electric clippers with size 40 blades. The shoulder, mid-side, britch and back positions (fixed positions) were sampled from the right-hand side. On the left-hand side, five random positions were sampled. A square was drawn on plastic material to cover the sheep's side. That square was divided into numbered squares. The numbers of the squares to be sampled were obtained from a random digits table (Snedecor and Cochran, 1980). The same five random positions were sampled from all sheep. These random positions are shown in Figure 3.

Kemp score, colour, lustre and handle were subjectively assessed as described in Chapter 1. Under the same conditions staple length, yield, medullation index, bulk, resilience and tristimulus colour values (X, Y and Z) were also measured and recorded.

Data were analysed using REG, a generalised linear models computing package (Gilmour, 1981).

Correlation coefficients were estimated between traits of each of the fixed positions (on the right-hand side) and the average of random positions (on the left-hand side).

2.2.2 Fixed Positions Study

In a separate study the data collected for Chapter 1 were also used to provide more information about sampling positions. It was decided to exclude the rump and withers positions from Flock A and

Figure 3. Random positions sampled for various wool traits.

study four fixed positions (shoulder, mid-side, britch and back) in both flocks. Fixed positions are shown in Figure 1.

The correlation coefficients between each fixed position and the average of the four fixed positions in the same shearing as well as in later shearings were calculated within flock-sex groups for each shearing. The Z-transformation was used in pooling over sexes and flocks for each trait for each position (Snedecor and Cochran, 1980). Correlation coefficients showed no significant differences either between sexes or between flocks. In the same way, correlations were pooled across shearings again because no significant differences were found between shearings.

For each shearing, analysis of variance was conducted for each of the studied positions within flock-sex groups. Preliminary analyses indicated that birth rank and age of dam were important fixed effects to be included in the model with the random sire effect. Date of birth was an important covariate. Sire x birth rank was the only significant interaction. The expected values of the mean squares were obtained as described in Chapter 1.

Phenotypic variances ($\sigma^2s + \sigma^2e$) were calculated from the sire (s) and residual (e) variance components for each trait for each position within flock-sex groups. The flock-sex estimates were pooled, weighting according to the sire and residual degrees of freedom to produce mean values for each trait for each position.

The sire variance ratio [$\sigma^2s/(\sigma^2s + \sigma^2e)$] was calculated within flock-sex groups for each trait for each position within and across shearings. The average of this ratio was based on unweighted means since the estimates of the variances were not significantly different (Robertson, 1959).

2.3 RESULTS AND DISCUSSION

The six criteria by which the best sampling position may be judged are shown for each trait in Tables 2.3.1 to 2.3.6. Pooled estimates over the three shearings were included since the goal was to reach an overall decision. However, the results obtained from individual shearings are also presented.

For each trait this *'best'* position can be picked for each of the six criteria, then a comparison between positions can be used to choose that position which in general satisfies most principles. Ranking of positions has been made by using the *'best'* position as the base (=100), other positions being compared to it.

Kemp score data showed that the mid-side sample had the closest value to the overall mean, highest phenotypic variation and highest correlations with average of fixed and average of random positions. The shoulder position gave the best prediction of later fleeces as well as highest sire variance ratio.

It was also found from the handle data that the mid-side sample had the closest value to the fleece mean, highest correlations with the average of random samples and best prediction of later fleeces. The shoulder position maximised the phenotypic variation in handle grades. The correlations with the average of fixed positions were the highest for shoulder and mid-side positions. The highest sire variance ratio was found on the back position.

For medullation index, the shoulder position had the closest value to the overall mean as well as the best prediction of later fleeces. The correlations with the average of fixed and average of random positions were found to be the highest in the shoulder sample. While the highest sire variance ratio was found on the back position, the maximum phenotypic variation was estimated in the britch sample.

Regarding fleece coarseness and medullation, the foregoing results (Tables 2.3.1 to 2.3.6) suggest that shoulder samples most often satisfied the six criteria considered for the best sampling position.

Table 2.3.1 *Sire variance ratio* $[\sigma^2 s/(\sigma^2 s + \sigma^2 e)]$ for various wool traits estimated from different positions in the three shearings

	SH	MS	BR	BK		SH	MS	BR	BK
KS	0.06	0.00	0.07	0.05	STL	0.13	0.09	0.15	0.11
	0.22	0.05	0.11	0.06		0.02	0.00	0.00	0.14
	0.22	0.18	0.23	0.02		0.23	0.20	0.09	0.33
	0.16	0.06	0.13	0.05		0.12	0.09	0.08	0.18
HG	0.05	0.05	0.02	0.07	YLD	0.02	0.10	0.09	0.05
	0.06	0.09	0.07	0.05		0.12	0.15	0.06	0.10
	0.04	0.13	0.09	0.24		0.29	0.13	0.13	0.01
	0.05	0.09	0.06	0.11		0.13	0.13	0.09	0.05
MI	0.02	0.18	0.01	0.23	CWA	0.09	0.04	0.10#	0.12#
	0.19	0.00	0.22	0.14		0.12	0.03	0.03	0.17
	0.11	0.19	0.18	0.10		0.35	0.18	0.03	0.20
	0.10	0.12	0.13	0.16		0.17	0.08	0.05#	0.17#
GCG	0.12	0.13	0.15	0.09	GWA	0.13	0.00	0.15#	0.10#
	0.22	0.06	0.10	0.04		0.15	0.08	0.08	0.18
	0.03	0.08	0.00	0.10		0.26	0.21	0.01	0.29
	0.13	0.09	0.09	0.08		0.17	0.08	0.07#	0.20#
X	0.11	0.13	0.06	0.16	LG	0.10	0.33	0.17	0.03
	0.12	0.14	0.13	0.07		0.12	0.08	0.08	0.00
	0.33	0.12	0.07	0.08		0.05	0.03	0.02	0.01
	0.17	0.13	0.09	0.11		0.09	0.16	0.10	0.02
Y	0.11	0.13	0.06	0.10	BUL	0.07	0.06	0.06	0.12
	0.13	0.08	0.14	0.08		0.24	0.15	0.03	0.20
	0.34	0.12	0.07	0.13		0.20	0.04	0.11	0.26
	0.18	0.11	0.09	0.10		0.17	0.09	0.06	0.19
Z	0.14	0.15	0.08	0.05	RES	0.07	0.08	0.04	0.05
	0.14	0.09	0.14	0.07		0.18	0.06	0.01	0.17
	0.25	0.10	0.09	0.06		0.12	0.11	0.03	0.19
	0.17	0.11	0.10	0.06		0.12	0.08	0.03	0.13
Y-Z	0.16	0.15	0.11	0.14					
	0.15	0.03	0.15	0.04					
	0.11	0.09	0.12	0.12					
	0.14	0.09	0.12	0.10					

Estimates are arranged in descending order of shearings, 1, 2, 3, and pooled estimate over the three shearings.

2 observations missing from Flock A at the first shearing.

Table 2.3.2 *Phenotypic variance* ($\sigma^2 s + \sigma^2 e$) for various wool traits estimated from different positions in the three shearings

	SH	MS	BR	BK		SH	MS	BR	BK
KS	0.20	0.30	0.33	0.22	STL	2.78	2.87	3.09	3.05
	0.45	0.69	0.39	0.40		2.52	2.66	2.00	6.49
	0.69	0.68	0.82	0.36		3.89	3.24	3.88	8.71
	0.41	0.53	0.47	0.31		2.96	2.89	2.90	5.64
HG	0.90	0.62	0.56	0.53	YLD	19.24	25.16	55.60	26.06
	0.27	0.27	0.26	0.39		18.78	28.74	45.76	14.05
	0.35	0.35	0.20	0.27		26.08	29.72	34.53	12.53
	0.54	0.43	0.37	0.42		16.10	27.53	47.01	18.55
MI	65.20	79.08	80.85	59.92	CWA	20.86	13.11	12.63#	16.74#
	36.25	24.25	33.56	31.62		16.52	12.78	22.87	18.00
	50.86	34.17	44.11	42.28		29.50	24.74	25.32	24.73
	51.56	48.90	55.31	45.70		21.45	15.83	20.76#	19.65#
GCG	0.79	0.84	1.09	0.44	GWA	13.46	9.33	11.35#	19.87#
	0.49	0.39	0.34	0.36		23.20	20.45	31.38	25.29
	0.43	0.46	0.26	0.46		35.58	43.35	34.81	34.29
	0.60	0.59	0.62	0.42		22.27	21.53	26.84#	26.46#
X	6.23	6.04	8.54	12.79	LG	0.13	0.07	0.32	0.24
	2.90	2.03	3.35	4.72		0.29	0.16	0.24	0.28
	3.77	2.60	2.83	8.22		0.20	0.17	0.33	0.38
	4.46	3.80	5.33	8.85		0.20	0.13	0.29	0.29
Y	6.80	6.95	9.97	14.59	BUL	17.41	17.65	23.46	23.69
	3.51	2.83	3.81	7.18		3.89	3.41	2.80	3.39
	3.90	17.78	2.90	7.44		3.74	3.52	3.57	4.30
	4.94	8.15	6.09	10.25		9.34	9.21	11.37	11.84
Z	21.05	17.36	22.01	23.54	RES	2.43	2.37	3.08	3.52
	7.97	4.49	9.65	8.51		0.89	0.64	0.59	0.63
	8.03	7.58	6.33	18.00		0.93	1.25	0.94	0.99
	13.29	10.47	13.85	16.92		1.52	1.49	1.69	1.89
Y-Z	6.66	3.84	4.24	7.77					
	1.93	1.08	1.95	4.41					
	1.44	1.85	1.04	4.95					
	3.73	2.39	2.66	5.90					

Estimates are arranged in descending order of shearings 1, 2, 3, and pooled estimate over the three shearings.

2 observations missing from Flock A at the first shearing.

Table 2.3.3 Correlations of various wool traits taken from different positions with fleece average estimated from *fixed positions* in the three shearings

	SH	MS	BR	BK		SH	MS	BR	BK
KS	0.64	0.68	0.67	0.66	STL	0.88	0.87	0.88	0.87
	0.70	0.78	0.74	0.60		0.84	0.90	0.80	0.82
	0.78	0.81	0.68	0.63		0.81	0.92	0.80	0.79
	0.71	0.76	0.70	0.63		0.85	0.90	0.84	0.83
HG	0.89	0.84	0.81	0.70	YLD	0.75	0.74	0.86	0.64
	0.65	0.67	0.65	0.70		0.77	0.73	0.76	0.54
	0.74	0.82	0.59	0.53		0.87	0.82	0.85	0.68
	0.78	0.78	0.71	0.66		0.80	0.76	0.83	0.62
MI	0.91	0.92	0.89	0.88	CWA	0.80	0.79	0.77#	0.72#
	0.84	0.82	0.80	0.83		0.79	0.82	0.83	0.68
	0.79	0.80	0.72	0.76		0.77	0.79	0.80	0.77
	0.86	0.86	0.82	0.84		0.79	0.80	0.81#	0.72#
GCG	0.81	0.76	0.85	0.61	GWA	0.84	0.83	0.76#	0.76#
	0.72	0.54	0.72	0.44		0.81	0.86	0.85	0.73
	0.80	0.77	0.54	0.55		0.74	0.81	0.78	0.74
	0.78	0.70	0.74	0.53		0.80	0.84	0.81#	0.74#
X	0.80	0.82	0.80	0.78	LG	0.64	0.56	0.76	0.66
	0.76	0.74	0.76	0.65		0.59	0.48	0.61	0.64
	0.78	0.80	0.73	0.68		0.65	0.73	0.69	0.67
	0.78	0.79	0.77	0.71		0.62	0.59	0.69	0.66
Y	0.81	0.81	0.79	0.79	BUL	0.57	0.76	0.58	0.62
	0.75	0.69	0.71	0.64		0.81	0.82	0.72	0.74
	0.77	0.80	0.72	0.68		0.88	0.88	0.80	0.84
	0.78	0.77	0.75	0.71		0.77	0.82	0.70	0.73
Z	0.84	0.80	0.82	0.72	RES	0.55	0.63	0.54	0.58
	0.80	0.72	0.80	0.60		0.80	0.70	0.69	0.65
	0.76	0.82	0.74	0.72		0.80	0.82	0.78	0.78
	0.81	0.78	0.80	0.68		0.73	0.72	0.67	0.67
Y-Z	0.87	0.79	0.84	0.64					
	0.77	0.64	0.72	0.64					
	0.75	0.83	0.75	0.75					
	0.81	0.76	0.78	0.67					

Correlations are arranged in descending order of shearings 1, 2, 3, and pooled estimates over the three shearings.

\# 2 observations missing from Flock A at the first shearing

For shearings 1, 2 and 3: $r>0.257$ ($p<0.05$), $r>0.333$ ($p<0.01$)
For pooled correlations: $r>0.19$ ($p<0.05$), $r>0.25$ ($p<0.01$).

Table 2.3.4. Correlations of various wool traits taken from different positions with fleece average estimated from *random positions* in the three shearings

	SH	MS	BR	BK		SH	MS	BR	BK
KS	0.00	0.69	0.00	0.63	Y-Z	0.79	0.79	0.83	0.46
	0.78	0.48	0.76	0.28		0.64	0.63	0.35	0.66
	0.69	0.69	0.33	0.69		0.59	0.25	0.55	-0.02
	0.56	0.63	0.42	0.56		0.68	0.60	0.62	0.40
HG	0.23	0.23	0.20	0.00	STL	0.68	0.68	0.91	0.93
	0.54	0.83	0.63	0.27		0.86	0.82	0.77	0.59
	0.18	0.31	0.60	0.41		0.58	0.71	0.52	0.48
	0.33	0.52	0.52	0.23		0.73	0.74	0.78	0.74
MI	0.12	-0.13	-0.08	0.63	YLD	0.90	0.92	0.77	0.39
	0.47	0.27	-0.02	-0.08		0.84	0.64	0.12	0.41
	0.80	0.16	0.54	0.13		0.86	0.76	0.73	0.73
	0.52	0.10	0.17	0.26		0.87	0.80	0.60	0.53
GCG	0.26	0.60	0.39	0.01	LG	-0.33	-0.22	-0.65	-0.36
	0.83	0.18	0.11	0.11		0.59	0.19	0.00	0.35
	0.84	0.84	-0.09	0.15		0.10	0.52	0.16	0.55
	0.71	0.60	0.14	0.09		0.14	0.18	0.20	0.20
X	0.88	0.90	0.86	0.84	BUL	0.60	0.52	0.52	0.75
	-0.14	0.28	-0.14	0.47		0.83	0.74	0.57	0.20
	0.19	0.07	0.03	0.04		0.76	0.94	0.82	0.85
	0.44	0.54	0.37	0.53		0.74	0.80	0.66	0.67
Y	0.89	0.89	0.87	0.86	RES	0.19	-0.04	-0.17	0.29
	-0.20	0.26	-0.11	0.47		0.74	0.71	-0.13	0.29
	0.19	0.12	0.06	0.05		0.58	0.80	0.52	0.76
	0.44	0.54	0.40	0.55		0.54	0.57	0.09	0.49
Z	0.74	0.81	0.78	0.59					
	0.25	0.45	0.11	0.59					
	0.43	0.10	0.01	-0.23					
	0.50	0.52	0.37	0.36					

Correlations are arranged in descending order of shearings, 1, 2, 3, and pooled estimate over the three shearings.

For shearing 1: $r>0.63$ ($p<0.05$), $r>0.77$ ($p<0.01$).

For shearings 2 and 3: $r>0.75$ ($p<0.05$), $r>0.87$ ($p<0.01$).

For pooled correlations: $r>0.48$ ($p<0.05$), $r>0.59$ ($p<0.01$).

Table 2.3.5 Correlations of various wool traits taken from different positions in the first and second shearings with the *later fleece averages* estimated from fixed positions.

	SH	MS	BR	BK		SH	MS	BR	BK
KS	0.43	0.28	0.22	0.23	STL	0.44	0.34	0.46	0.53
	0.18	0.13	0.09	0.21		0.15	-0.01	0.22	0.12
	0.45	0.33	0.35	0.26		0.33	0.34	0.39	0.47
HG	0.35	0.36	0.35	0.32	YLD	0.33	0.26	0.37	0.09
	0.15	0.24	0.19	0.23		0.37	0.18	0.31	0.23
	0.14	0.39	0.30	0.30		0.27	0.10	0.26	0.21
MI	0.49	0.46	0.32	0.42	CWA	0.23	0.25	0.23#	0.24#
	0.54	0.41	0.35	0.52		0.06	0.00	0.09#	0.05#
	0.43	0.43	0.37	0.50		0.30	0.37	0.25	0.36
GCG	0.15	0.10	0.18	0.13	GWA	0.25	0.30	0.18#	0.27#
	0.08	0.04	0.12	0.13		0.06	0.06	0.05#	0.15#
	0.11	0.03	-0.04	-0.02		0.31	0.37	0.27	0.42
X	0.43	0.24	0.21	0.00	LG	0.00	0.08	0.10	0.14
	0.26	0.26	0.26	0.16		0.05	-0.09	0.13	-0.12
	0.36	0.47	0.24	0.35		0.21	0.07	0.26	0.23
Y	0.42	0.24	0.18	0.03	BUL	0.38	0.48	0.49	0.31
	0.24	0.26	0.23	0.13		0.37	0.43	0.37	0.33
	0.37	0.43	0.25	0.29		0.74	0.57	0.46	0.59
Z	0.51	0.31	0.32	0.04	RES	0.31	0.33	0.26	0.18
	0.33	0.30	0.36	0.18		0.27	0.30	0.22	0.20
	0.39	0.57	0.31	0.33		0.62	0.47	0.43	0.52
Y-Z	0.48	0.35	0.35	0.10					
	0.45	0.30	0.40	0.30					
	0.38	0.50	0.37	0.27					

Estimates are arranged in descending order of correlations from first to second, first to third and from second to third shearings.

\# 2 observations missing from Flock A in the first shearing.

$r>0.257$ ($p<0.05$), $r>0.333$ ($p<0.01$).

Table 2.3.6 Least squares means and position effects for various traits

	KS	HG	MI	GCG	X	Y	Z
Mean	2.72	3.42	31.12	4.30	63.38	65.32	61.11
Position							
SH	-0.81	0.51	-1.79	0.23	0.36	0.39	0.42
MS	-0.31	0.22	1.93	0.26	2.10	2.16	3.16
BR	0.39	-0.46	3.41	-0.31	0.79	0.79	1.08
BK	0.74	-0.27	-3.55	-0.19	-3.25	-3.34	-4.66

	Y-Z	STL	YLD	LG	BUL	RES
Mean	4.20	15.73	77.86	3.66	23.09	7.99
Position						
SH	-0.03	0.49	-0.64	0.25	-1.14	-0.30
MS	-1.01	0.69	-1.27	0.14	0.04	-0.05
BR	-0.29	-0.57	-2.70	-0.15	0.84	0.09
BK	1.33	-0.61	4.61	-0.25	0.26	0.25

Sumner and Revfeim (1973) studied mean fibre diameter in data based on 10 Romney hoggets. Their data showed that the shoulder position had the highest correlation with the overall mean. Also, mean fibre diameter estimated from belly, mid-side and shoulder positions were very close to the overall mean. Sumner (personal communication) also measured fibre diameter in 50 fibres from 8 positions on 10 hoggets of each of the Merino, Cheviot and Drysdale breeds. The highest correlations with the fleece mean of fibre diameter were obtained from the britch point in Merino sheep, and from britch point and back positions in Cheviots. The highest correlation with fibre diameter mean in Drysdale fleeces was found in shoulder data.

For all subjective and objective colour criteria, there is a consistent trend for the shoulder position to have the highest sire variance ratio and highest correlations with the average of fixed positions. For tristimulus colour values, the shoulder position also had consistently the closest means to the overall means as well as best prediction from the first to the second shearing, while prediction of the third shearing from the second one was found to be the best from the mid-side. For greasy colour grade, the shoulder sample had the highest correlation with the average of random samples as well as the best predictability from the second to the third shearings, while the back position had the closest value to the overall mean and best predictability from the first to the third fleece.

The foregoing comparisons among positions might suggest that the shoulder sample can be taken as the best sampling position representing fleece colour since the six criteria were met most often by samples from this position. Bigham *et al.* (1984b) calculated the correlations between each position and overall fleece mean for Y and Y-Z values in Romney, Coopworth and Perendale data. Their correlations were based on a small number of animals. However, they concluded that the mid-side position was a suitable site to indicate the degree of discolouration. Despite this conclusion, their correlations based on shoulder samples were generally higher than those from mid-side samples.

In staple length the back position gave the highest sire variance ratio, the highest phenotypic variation and generally the best predictability to later fleeces. Staple length of the shoulder sample was the closest to the overall mean. The highest correlations with the fleece average were found on the britch position for random samples and on the mid-side position for fixed samples. These comparisons suggest that the back is generally a suitable position for staple length.

For yield, the shoulder sample had the closest value to the overall mean, highest correlation with the average of random samples and generally the best prediction of later fleeces. The highest sire variance ratio was found in shoulder and mid-side samples. The britch position had the maximum phenotypic variation and the highest correlations with the average of fixed positions in the fleece. Overall the shoulder was generally the best sampling position for yield measurement.

Data on clean wool per unit area indicated that shoulder samples had the greatest phenotypic variation while britch samples had the highest correlation with the average of fixed positions. Highest sire variance ratio was found in both shoulder and britch positions. The mid-side sample in general gave the best prediction of later fleeces, bearing in mind that both greasy and clean wool per unit area were obtained from shoulder and mid-side positions only at the first shearing in Flock A. These results suggest the shoulder as the best sampling position for clean wool production.

For greasy wool per unit area, the back position had the highest sire variance ratio, and best prediction of the third shearing. Britch and back positions had the highest phenotypic variation. The mid-side sample had the highest correlation with the average of fixed position and prediction of the second shearing would be better if the mid-side sample in the first shearing was used. Generally, the back performed best in representing greasy wool production.

Lustre of mid-side samples had the highest sire variance ratio as well as the closest value to the overall mean. The britch sample generally gave better prediction of later fleeces and had the highest correlation with the average of fixed positions. When the maximum phenotypic variation and highest correlations with the average of random samples were considered, britch and back positions had similar results. Overall the britch seemed the best sampling position for lustre grade.

Bulk and resilience are often highly correlated, also they showed similar trends for these six criteria of sampling positions. The back position had the highest sire variance ratio and maximum phenotypic variation in both traits. The mid-side sample had the closest value to the overall mean, and generally the highest correlations with averages of fixed and random positions. Predicting averages of bulk and resilience at later fleeces was best when it was made from the mid-side at the first shearing and from the shoulder at the second shearing. The mid-side can be generally taken as the best sampling position for bulk and resilience.

Bigham *et al.* (1984a) estimated the correlations between each position and overall fleece mean for loose wool bulk in Romneys, Coopworths and Perendales. Their correlations were based on 15 hoggets from each breed. They reported that all positions were equally suitable for ranking sheep for loose wool bulk and concluded the mid-side as a good representative position for loose wool bulk in the fleece. However, their correlations obtained from shoulder samples were generally higher than those obtained from the mid-side.

The foregoing comparisons among these four positions studied showed that the shoulder can be considered as the best sampling position for coarseness, colour, yield and clean wool per unit area. The back position might be more satisfactory for staple length and greasy wool per unit area. For bulk and resilience the mid-side was favoured and lustre would be better if it is assessed from the britch sample.

To reach an overall decision it seems that the shoulder sample most often satisfies the six criteria for all traits. The shoulder was also considered to be convenient for sampling (Chapman and Young, 1957; Lockart, 1954).

Perhaps the most disturbing aspect of this study was the low values of many of these correlations, particularly those between different fleeces. These low values do not lead to great confidence in the accuracy of prediction of fleece means from samples of any position.

2.4 CONCLUSIONS

Overall the shoulder appears the best position for sampling Drysdale fleeces for breeding purposes. Shoulder samples tended to have higher correlations with fleece averages estimated from fixed and random positions and the closest mean to the overall fleece mean. Traits assessed from the shoulder samples generally had higher phenotypic variation and the prediction of later fleeces tended to be more accurate. There was an indication that more of the variation on shoulder samples tended to be of genetic origin.

APPENDIX 1
SOME OBSERVATIONS ON A DYEBANDING TECHNIQUE

Hair growth occurs in cycles in which periods of active growth alternate with periods of rest (Dry, 1926; Rougeot, 1961; Chase and Sliver, 1969). After a period of growth (anagen) fibre production slows. This is associated with a reduction in diameter and loss of medulla and pigmentation (in coloured fibres). The follicle bulb and papilla shrink in size and the follicle becomes shorter and wrinkled. A keratinised 'brush' is formed at the root end of the fibre. The shrunken bulb and papilla remain dormant at the base of the follicle. The growth of a new fibre is preceded by enlargement of the bulb. Then cells produced in the bulb begin to migrate up the follicle differentiating into a new hair cone and the tip of a new fibre. Animals usually grow new fibres before the old ones moult from the follicle.

There is a considerable variation in the length of the phase of the cycle. The duration of the growing phase is genetically controlled and is characteristic for each hair type while the duration of resting phase (telogen) is variable and can be modified by photoperiodic manipulations, hormones, trauma and plucking (Ebling, 1965; Slee, 1965; Rougeot *et al.*, 1984). Thus a hair may be anchored in the skin by its club root for several months without growing.

In sheep, artificial selection has led to elimination of the hair cycle from many follicles. However, some primary follicles still exhibit these cycles as shown by the intermittent production of kemp fibres. A study of the kemp growth cycle can be made either from coat observations (Ross and Wright, 1954; Guirgis, 1967; Elgabbas, 1978) or from follicle studies (Rougeot, 1961; Ryder, 1969). However, it is not easy to ascertain precisely when the various stages of the hair cycle occur from coat observations. Similarly, interpretation of skin sections is often not easy and there is the risk that the cycle will be modified by the trauma of removing pieces of skin.

Kemp fibre generations have been observed (Ross and Wright, 1954; Guirgis, 1967; Elgabbas, 1978) and it has been suggested that the first kemp generation sheds at about 2 months of age and later generations shed at 4 month intervals. However, the timing of the hair cycles has not been confirmed experimentally. Borum (1954) has shown that dyeing of fibres can be a very useful technique for studying hair cycles in mice, and it was decided to attempt to adapt the dyebanding technique of Chapman and Wheeler (1963) to a study of kemp growth cycles.

A plan was made to study the growth cycle of kemp fibres in which ten Drysdale (N^dN^d) ewe lambs from the Massey University flock were chosen at random in September 1981. At 2 months of age, four staples were tied in shoulder, mid-side, britch and back following the technique of Guirgis (1967). Staples were dyed at skin level using the Durafur black solution recommended by Wheeler *et al.* (1977). The fleece was opened and dye was applied evenly to the fibres at the skin level using a fine glass pipette. Dye was applied at monthly intervals. Using fine scissors, dyebanded staples were collected the day before shearings in December 1981, April 1982 and September 1982. Dyebanded staples collected were examined and separated into different fibre types (kemp, medullated and non-medullated fibres).

While dye was applied at monthly intervals, examination showed that with many fibres there were less dyebands than applications. It was not possible to ascertain which was missing or why. McClelland (personal communication) followed exactly the same technique in Romney sheep and found that all her dyebands were reasonably clear although in some samples dyebands were not as well defined as in others.

The variable numbers of dyebands observed in the present study might be due to changes in follicle activity. The fibre produced by a follicle in the growing phase is likely to be marked in a new band each time dye is applied. However, a fibre in the resting stage may well receive two or more applications of dye at the same place.

While the present study has not been successful in achieving the desired results, it has indicated that with minor modifications, dyeing could be useful in studying kemp cycles. Different coloured dyes might be suitable to determine the time of the various bands. To avoid colours confounding, lighter colours should be used at earlier applications.

APPENDIX 2

CORRELATIONS OF SHOULDER AND MID-SIDE WOOL TRAITS WITH FLEECE AVERAGES AT SHEARINGS 1, 2 AND 3 IN BOTH FLOCKS

Table A1. Correlations between shoulder wool traits and fleece average at shearings 1, 2 and 3 in Flock A (pooled over sexes)

Sh → Av ↓	KS	HG	MI	CCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS	0.47	-0.40	-0.01	0.12	0.13	0.33	0.35	0.29	-0.10	0.03	-0.14	0.18	0.07	-0.08	0.25	0.19
	0.75	-0.19	0.37	0.27	0.47	0.36	0.36	0.50	-0.52	-0.08	0.43	-0.23	-0.09	-0.12	0.55	0.41
	0.78	-0.16	-0.31	-0.02	0.42	0.15	0.13	0.28	-0.40	-0.32	-0.18	-0.42	-0.41	-0.05	0.31	0.36
HG	-0.45	0.89	0.19	0.22	-0.02	-0.19	-0.21	-0.18	0.07	-0.08	0.13	-0.06	-0.04	0.29	-0.35	-0.29
	-0.40	0.52	-0.24	-0.08	-0.18	-0.19	-0.24	-0.27	0.24	-0.24	-0.19	-0.16	-0.19	0.26	-0.57	-0.52
	-0.24	0.65	-0.31	0.08	-0.04	-0.12	-0.11	-0.02	-0.11	0.05	-0.28	0.22	0.08	0.25	-0.37	-0.26
MI	-0.07	0.26	0.83	0.14	0.12	0.29	0.27	0.28	-0.20	0.02	0.09	-0.15	-0.14	-0.04	0.18	-0.03
	0.33	0.16	0.71	0.18	0.19	0.44	0.45	0.35	-0.04	-0.07	0.18	-0.09	0.00	-0.29	-0.06	-0.18
	-0.30	-0.16	0.71	0.34	-0.16	0.28	0.29	0.11	0.16	0.31	0.24	0.18	0.24	-0.35	0.03	-0.08
CCG	-0.10	0.20	0.08	0.71	0.38	0.20	0.21	0.27	-0.26	-0.20	0.17	-0.20	-0.16	0.44	-0.09	0.00
	0.28	-0.01	0.24	0.70	0.35	0.44	0.45	0.54	-0.45	-0.20	0.28	-0.30	-0.21	-0.08	0.11	0.03
	-0.04	0.14	0.17	0.77	0.30	0.31	0.26	0.33	-0.25	0.04	0.13	0.29	0.31	0.18	-0.03	-0.06
SCG	-0.01	0.02	0.24	0.45	0.72	0.45	0.47	0.59	-0.53	-0.14	0.06	-0.11	-0.09	0.22	0.23	0.09
	0.29	0.03	0.38	0.30	0.56	0.51	0.49	0.60	-0.52	-0.19	0.20	-0.21	-0.15	-0.11	0.01	-0.11
	0.37	0.18	-0.06	0.06	0.67	0.41	0.41	0.59	-0.66	-0.43	-0.41	-0.33	-0.41	0.06	0.27	0.26
X	0.05	-0.13	0.31	0.28	0.49	0.76	0.78	0.71	-0.30	-0.06	-0.12	0.08	0.06	0.08	0.07	-0.10
	0.37	0.11	0.45	0.17	0.26	0.56	0.53	0.53	-0.29	0.15	0.29	0.15	0.22	-0.28	-0.15	-0.23
	0.01	-0.16	0.36	0.42	0.35	0.77	0.76	0.68	-0.40	-0.04	0.19	-0.04	0.03	-0.17	0.19	0.08
Y	0.10	-0.14	0.29	0.33	0.49	0.76	0.79	0.70	-0.28	-0.06	-0.13	0.10	0.08	0.06	0.07	-0.10
	0.40	0.01	0.49	0.18	0.19	0.56	0.55	0.49	-0.20	0.10	0.21	0.14	0.19	-0.31	0.01	-0.07
	0.01	-0.15	0.36	0.41	0.35	0.76	0.76	0.68	-0.39	-0.04	0.19	-0.04	0.04	-0.11	0.19	0.08
Z	0.01	-0.13	0.32	0.45	0.62	0.70	0.71	0.76	-0.54	-0.15	-0.06	-0.06	-0.06	0.15	0.11	-0.02
	0.44	0.02	0.46	0.24	0.23	0.52	0.50	0.58	-0.45	0.12	0.30	0.05	0.13	-0.26	-0.03	-0.14
	0.18	-0.04	0.24	0.39	0.54	0.75	0.74	0.79	-0.64	-0.16	-0.04	-0.15	-0.14	-0.02	0.23	0.18
Y-Z	0.10	0.01	-0.24	-0.52	-0.66	-0.25	-0.23	-0.57	0.84	0.25	-0.15	0.37	0.35	-0.28	-0.15	-0.17
	-0.30	-0.11	-0.19	-0.24	-0.51	-0.23	-0.21	-0.45	0.66	-0.05	-0.32	0.14	0.04	0.02	0.02	0.[illegible]8
	-0.35	-0.11	0.01	-0.22	-0.65	-0.52	-0.51	-0.70	0.77	0.25	0.31	0.25	0.32	-0.10	-0.22	-0.24
STL	-0.04	-0.11	-0.03	-0.10	-0.24	-0.04	-0.01	-0.16	0.29	0.82	-0.16	0.44	0.41	0.13	0.15	-0.02
	-0.12	-0.15	0.00	-0.11	-0.10	0.07	0.09	0.08	0.02	0.77	-0.04	0.51	0.25	-0.24	-0.17	-0.17
	-0.32	-0.10	0.27	-0.19	-0.44	-0.17	-0.19	-0.25	0.26	0.73	0.20	0.29	0.31	-0.14	-0.36	-0.40
YLD	0.08	0.15	0.17	-0.04	-0.15	-0.23	-0.24	-0.16	-0.02	-0.05	0.80	-0.25	-0.09	-0.01	0.03	-0.04
	0.38	-0.18	0.10	0.35	0.14	0.06	0.08	0.21	-0.35	-0.14	0.81	-0.14	0.09	0.05	-0.05	-0.05
	-0.25	-0.13	-0.02	0.21	-0.19	0.07	0.06	-0.10	0.27	0.20	0.81	0.43	0.65	0.01	-0.32	-0.41
GWA	0.17	0.06	-0.08	-0.09	-0.09	0.20	0.23	0.01	0.32	0.53	-0.34	0.86	0.79	0.02	-0.13	-0.25
	-0.31	-0.26	0.01	-0.27	-0.28	0.07	0.10	-0.10	0.38	0.56	-0.06	0.84	0.76	-0.01	-0.13	-0.08
	-0.22	0.00	-0.09	-0.18	-0.45	-0.20	-0.19	-0.35	-0.07	0.29	0.19	0.69	0.64	0.24	-0.53	-0.45
CWA	0.19	0.08	-0.07	-0.05	-0.06	0.19	0.22	0.02	0.29	0.57	-0.13	0.84	0.82	0.04	-0.16	-0.29
	-0.22	-0.33	-0.02	-0.11	-0.24	0.08	0.11	-0.02	0.24	0.54	0.22	0.81	0.81	0.07	-0.16	-0.09
	-0.29	-0.06	-0.09	-0.10	-0.46	-0.15	-0.15	-0.33	0.49	0.33	0.43	0.72	0.76	0.21	-0.55	-0.52
LG	-0.03	0.25	0.09	0.20	0.09	0.04	0.05	0.04	-0.02	0.24	0.14	0.10	0.13	0.60	-0.15	-0.15
	-0.54	0.11	-0.35	-0.18	-0.30	-0.31	-0.33	-0.39	0.33	0.11	-0.09	0.24	0.21	0.55	-0.38	-0.24
	0.12	0.24	0.21	-0.15	-0.08	-0.24	-0.24	-0.14	-0.04	-0.08	-0.07	0.25	0.20	0.68	-0.50	-0.31
BUL	0.26	-0.20	0.15	0.08	0.28	0.25	0.29	0.32	-0.17	-0.10	-0.12	-0.13	-0.15	0.00	0.79	0.55
	0.45	-0.26	0.32	0.18	0.43	0.35	0.36	0.42	-0.36	-0.23	-0.02	-0.21	-0.21	-0.20	0.87	0.74
	0.29	-0.09	-0.05	0.16	0.49	0.22	0.22	0.34	-0.39	-0.50	-0.26	-0.52	-0.54	-0.22	0.82	0.78
RES	0.20	-0.16	0.02	0.08	0.25	0.15	0.15	0.25	-0.31	-0.18	-0.07	-0.24	-0.25	0.02	0.66	0.67
	0.28	-0.27	0.13	0.12	0.26	0.23	0.25	0.32	-0.30	-0.26	-0.12	-0.14	-0.18	-0.12	0.84	0.60
	0.30	-0.03	-0.20	0.10	0.43	0.10	0.10	0.24	-0.35	-0.50	-0.29	-0.49	-0.56	-0.06	0.71	0.75

Correlations are arranged in descending order of shearings 1, 2 and 3.

$r>0.271$ ($p<0.05$), $r>0.351$ ($p<0.01$).

Sh = shoulder, Av = Average of the fleece.

Table A2 Correlations between mid-side wool traits and fleece average at shearings 1, 2 and 3 in Flock A (pooled over sexes)

MS → Av ↓	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS	0.54	-0.36	-0.16	0.27	0.08	0.37	0.41	0.28	0.03	0.05	-0.06	0.12	0.10	-0.03	0.40	0.27
	0.71	-0.27	0.05	0.35	0.21	0.21	0.20	0.25	-0.31	-0.04	0.39	-0.19	-0.08	-0.17	0.46	0.25
	0.76	-0.09	-0.33	-0.06	0.32	0.12	0.13	0.26	-0.40	-0.36	-0.06	-0.24	-0.27	-0.12	0.15	0.26
HG	-0.04	0.80	0.26	0.03	0.07	-0.02	-0.06	0.06	-0.23	-0.17	0.16	0.01	0.06	0.04	-0.41	-0.38
	-0.36	0.56	0.14	-0.05	-0.22	-0.21	-0.23	-0.24	0.20	-0.31	-0.11	-0.18	-0.21	0.24	-0.45	-0.34
	-0.12	0.75	-0.27	0.24	0.14	-0.02	-0.01	0.07	-0.12	-0.18	0.17	0.02	0.10	0.43	-0.37	-0.16
MI	0.00	0.27	0.84	-0.04	0.39	0.45	0.42	0.44	-0.29	-0.06	0.15	-0.08	-0.06	-0.02	0.10	-0.15
	0.24	-0.12	0.65	0.21	0.17	0.24	0.24	0.19	-0.08	0.16	0.13	0.04	0.08	0.00	0.04	-0.17
	-0.32	-0.43	0.79	0.20	-0.24	0.40	0.34	0.15	0.07	0.48	-0.09	0.04	0.01	-0.38	0.06	-0.25
GCG	0.13	0.10	-0.02	0.49	0.24	0.23	0.23	0.31	-0.34	-0.18	-0.02	0.09	0.11	0.12	0.11	0.04
	0.31	-0.20	0.15	0.54	0.29	0.35	0.33	0.40	-0.44	-0.05	0.47	-0.41	-0.24	0.06	0.31	0.24
	-0.01	0.05	0.07	0.71	-0.04	0.20	0.19	0.25	-0.22	0.00	0.19	-0.24	-0.14	-0.08	0.08	-0.05
SCG	0.17	0.01	0.10	0.32	0.69	0.59	0.60	0.69	-0.51	-0.08	-0.07	-0.04	-0.05	0.20	0.41	0.28
	0.22	0.01	0.16	0.28	0.43	0.49	0.49	0.56	-0.56	0.05	0.42	-0.18	-0.01	-0.06	0.13	0.06
	0.37	0.12	-0.14	0.09	0.57	0.49	0.48	0.65	-0.69	-0.32	-0.13	-0.14	-0.17	0.00	0.07	0.10
X	0.28	-0.08	0.13	0.10	0.51	0.85	0.85	0.74	-0.26	-0.02	-0.20	0.12	0.09	0.31	0.26	0.04
	0.33	-0.31	0.27	0.27	0.36	0.56	0.55	0.54	-0.42	0.26	0.31	-0.04	0.10	0.02	0.04	-0.11
	0.05	-0.24	0.51	0.25	0.19	0.69	0.69	0.57	-0.34	0.06	0.13	0.04	0.09	-0.30	0.18	-0.05
Y	0.30	-0.09	0.11	0.11	0.48	0.84	0.85	0.73	-0.24	0.00	-0.22	0.14	0.10	0.31	0.27	0.05
	0.35	-0.35	0.27	0.30	0.41	0.58	0.57	0.56	-0.41	0.24	0.26	-0.03	0.10	-0.01	0.14	-0.02
	0.06	-0.24	0.50	0.24	0.18	0.69	0.69	0.57	-0.33	0.06	0.14	0.05	0.10	-0.28	0.19	-0.03
Z	0.20	-0.07	0.16	0.15	0.59	0.80	0.80	0.80	-0.46	-0.12	-0.14	0.03	0.00	0.25	0.27	0.15
	0.38	-0.29	0.20	0.32	0.35	0.54	0.54	0.59	-0.52	0.28	+0.37	-0.14	0.03	-0.05	0.13	-0.03
	0.24	-0.11	0.25	0.23	0.36	0.70	0.69	0.72	-0.60	-0.10	0.23	-0.05	-0.01	-0.21	0.18	0.06
Y-Z	0.11	-0.05	0.17	-0.18	-0.56	-0.35	-0.33	-0.59	0.77	0.30	-0.09	0.24	0.23	-0.07	-0.14	-0.29
	-0.30	0.08	0.00	-0.15	-0.06	-0.22	-0.20	-0.30	0.41	-0.13	-0.40	0.27	0.10	0.08	-0.08	0.02
	-0.40	-0.08	0.11	-0.12	-0.45	-0.49	-0.49	-0.69	0.77	0.25	0.09	0.14	0.15	0.05	-0.10	-0.15
STL	0.08	-0.12	0.02	-0.21	-0.20	0.01	0.05	-0.09	0.26	0.90	-0.24	0.60	0.56	0.24	0.17	-0.01
	-0.04	-0.33	-0.20	-0.13	0.12	0.20	0.27	0.20	-0.02	0.89	-0.06	0.40	0.40	0.05	-0.06	-0.06
	-0.21	-0.15	0.43	-0.15	-0.44	-0.12	-0.15	-0.28	0.35	0.83	0.04	0.32	0.30	-0.03	-0.33	-0.36
YLD	-0.05	0.15	0.33	0.02	0.14	-0.02	-0.06	0.03	-0.16	-0.28	0.71	-0.33	-0.18	-0.12	-0.07	-0.09
	0.34	-0.02	0.07	0.07	0.30	0.22	0.17	0.23	-0.26	-0.07	0.70	-0.30	-0.08	-0.04	0.09	-0.01
	-0.15	-0.22	0.34	0.04	-0.11	0.18	0.18	0.01	0.15	0.20	0.71	0.31	0.47	-0.01	-0.12	-0.23
GWA	0.14	0.07	-0.14	0.04	-0.31	0.15	0.20	0.04	0.24	0.69	-0.35	0.86	0.82	0.24	0.13	-0.04
	-0.20	-0.22	0.14	-0.15	0.22	0.20	0.23	0.07	0.20	0.60	-0.34	0.86	0.78	-0.04	0.08	0.05
	-0.31	0.02	0.20	-0.20	-0.33	-0.19	-0.19	-0.25	0.08	0.39	0.14	0.81	0.77	0.18	-0.35	-0.48
CWA	0.12	0.09	-0.09	0.04	-0.30	0.14	0.19	0.05	0.21	0.68	-0.17	0.84	0.83	0.24	0.12	-0.05
	-0.08	-0.25	0.15	-0.12	0.33	0.25	0.25	0.12	0.11	0.58	-0.10	0.78	0.80	-0.07	0.10	0.05
	-0.31	-0.07	0.26	-0.16	-0.34	-0.13	-0.13	-0.24	0.32	0.42	0.35	0.81	0.80	0.15	-0.34	-0.38
LG	0.14	0.13	-0.11	0.14	0.11	0.11	0.12	0.19	-0.26	0.25	-0.16	0.21	0.21	0.43	0.02	0.05
	-0.29	0.13	0.03	-0.09	-0.14	-0.15	-0.14	-0.23	0.33	-0.04	-0.17	0.12	0.08	0.21	-0.42	-0.22
	0.08	0.38	-0.35	0.02	0.20	-0.07	-0.05	0.09	-0.20	-0.20	0.20	0.15	0.19	0.70	-0.35	-0.10
BUL	0.29	-0.16	0.02	0.15	0.24	0.31	0.32	0.29	-0.11	0.03	0.09	-0.03	-0.03	0.09	0.85	0.53
	0.34	-0.37	0.08	0.33	0.12	0.08	0.09	0.14	-0.18	-0.12	0.14	-0.05	-0.02	-0.14	0.73	0.62
	0.34	-0.18	-0.27	0.00	0.11	0.03	0.04	0.13	-0.20	-0.44	-0.35	-0.42	-0.48	-0.39	0.81	0.74
RES	0.09	-0.17	-0.04	0.09	0.09	0.07	0.08	0.11	-0.12	-0.04	0.02	-0.13	-0.13	-0.03	0.66	0.62
	0.24	-0.26	-0.04	0.29	0.20	0.08	0.10	0.12	-0.16	-0.14	0.08	-0.06	-0.06	-0.13	0.73	0.70
	0.34	-0.10	-0.37	-0.01	0.08	-0.11	-0.10	0.02	-0.14	-0.46	-0.35	-0.39	-0.45	-0.33	0.76	0.79

Correlations are arranged in descending order of shearings 1, 2 and 3.
r>0.271 (p<0.05), r>0.351 (p<0.01).
MS = Mid-side, Av. = Average of the fleece

Table A3 Correlations between shoulder wool traits and fleece average at shearings 1, 2 and 3 in Flock B (pooled over sexes)

Sh → Av ↓	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLO	GWA	CWA	LG	BUL	RES
KS	0.73	-0.04	0.05	0.20	0.02	0.23	0.22	0.17	-0.08	-0.06	0.18	0.20	0.24	-0.07	-0.02	-0.03
	0.62	-0.10	0.33	0.04	0.03	0.38	0.36	0.32	-0.14	-0.12	-0.10	0.04	0.01	-0.34	0.47	0.26
	0.73	-0.04	0.19	-0.08	0.08	0.39	0.39	0.37	-0.19	-0.22	-0.17	0.04	-0.02	-0.08	0.48	0.40
HG	-0.04	0.84	-0.25	0.44	0.21	0.10	0.08	0.19	-0.27	-0.02	0.27	-0.18	-0.09	-0.01	-0.04	-0.05
	-0.24	0.72	-0.53	0.23	0.17	-0.24	-0.26	-0.15	-0.03	-0.23	0.10	-0.48	-0.44	0.42	-0.57	-0.34
	-0.22	0.77	-0.48	0.02	0.00	-0.30	-0.31	-0.22	-0.14	-0.36	0.36	-0.32	-0.18	0.36	-0.46	-0.37
MI	0.09	-0.32	0.95	-0.22	-0.06	0.10	0.14	-0.01	0.07	0.19	0.08	-0.03	-0.02	-0.08	0.44	0.38
	0.35	-0.43	0.90	0.20	0.14	0.57	0.58	0.45	-0.19	0.38	0.39	0.34	0.41	-0.60	0.38	0.14
	0.18	-0.25	0.85	0.42	0.22	0.56	0.56	0.54	-0.31	0.36	-0.28	-0.07	-0.16	-0.54	0.17	0.02
GCG	0.24	0.52	-0.18	0.85	0.51	0.44	0.40	0.54	-0.58	-0.05	0.35	-0.12	-0.03	0.04	-0.07	-0.07
	0.04	0.24	0.17	0.66	0.49	0.41	0.41	0.45	-0.42	-0.04	0.30	-0.19	-0.13	-0.13	-0.22	-0.13
	0.04	0.35	0.06	0.67	0.39	0.27	0.26	0.32	-0.40	-0.12	0.38	-0.44	-0.29	-0.19	-0.18	-0.20
SCG	-0.04	0.04	-0.08	0.41	0.87	0.73	0.70	0.83	-0.80	-0.25	-0.03	-0.26	-0.27	0.36	-0.12	-0.09
	-0.01	0.21	0.09	0.35	0.77	0.56	0.52	0.66	-0.69	-0.18	0.12	-0.30	-0.26	-0.09	0.04	0.05
	0.10	0.29	0.05	0.16	0.59	0.28	0.28	0.41	-0.67	0.27	0.14	-0.04	0.02	-0.10	-0.17	-0.20
X	0.08	-0.03	0.07	0.26	0.68	0.79	0.79	0.76	-0.58	-0.15	-0.04	-0.17	-0.19	0.31	-0.16	-0.18
	0.28	0.03	0.44	0.49	0.59	0.80	0.78	0.78	-0.58	-0.02	0.21	-0.10	-0.05	-0.36	0.24	0.21
	0.33	-0.02	0.56	0.33	0.46	0.72	0.72	0.79	-0.73	0.23	-0.13	-0.11	-0.15	-0.43	0.27	0.14
Y	0.08	-0.04	0.08	0.24	0.65	0.79	0.79	0.74	-0.56	-0.14	-0.05	-0.17	-0.20	0.31	-0.16	-0.17
	0.31	0.01	0.49	0.49	0.53	0.80	0.79	0.76	-0.55	-0.03	0.19	-0.04	0.02	-0.37	0.27	0.21
	0.33	-0.05	0.56	0.32	0.46	0.73	0.73	0.79	-0.72	0.24	-0.14	-0.09	-0.13	-0.44	0.29	0.16
Z	0.06	0.07	-0.09	0.38	0.79	0.79	0.78	0.85	-0.76	-0.23	-0.04	-0.24	-0.25	0.36	-0.16	-0.16
	0.24	0.11	0.41	0.50	0.71	0.82	0.78	0.85	-0.73	-0.01	0.23	-0.14	-0.08	-0.32	0.22	0.17
	0.20	0.17	0.37	0.28	0.43	0.53	0.53	0.65	-0.78	0.27	0.01	-0.17	-0.15	-0.32	0.05	-0.04
Y-Z	0.00	-0.19	0.30	-0.49	-0.80	-0.65	-0.61	-0.82	0.87	0.30	0.03	0.26	0.27	-0.35	0.13	0.10
	-0.07	-0.25	-0.16	-0.41	-0.81	-0.65	-0.56	-0.76	0.83	-0.03	-0.21	0.24	0.20	0.14	-0.08	-0.06
	0.02	-0.41	-0.03	-0.15	-0.29	-0.15	-0.14	-0.31	0.68	-0.25	-0.19	0.22	0.15	0.09	0.27	0.29
STL	-0.12	0.12	0.18	0.05	-0.21	-0.07	-0.05	-0.12	0.17	0.90	0.11	0.24	0.19	0.06	-0.12	-0.13
	-0.11	-0.16	0.29	0.11	-0.02	0.09	0.10	0.04	0.05	0.87	0.24	0.35	0.42	-0.16	-0.08	-0.17
	-0.29	-0.15	0.13	0.09	0.11	-0.06	-0.04	0.00	-0.12	0.84	0.21	0.18	0.24	-0.33	-0.24	-0.24
YLD	0.24	0.37	-0.09	0.33	0.09	0.05	0.04	0.13	-0.19	0.16	0.71	0.13	0.30	-0.04	-0.20	-0.24
	0.06	0.16	0.04	0.12	0.31	0.11	0.05	0.19	-0.32	0.13	0.71	-0.25	-0.06	-0.23	-0.03	-0.11
	0.12	-0.04	-0.15	0.33	0.18	-0.01	0.00	0.00	0.00	-0.04	0.92	-0.21	0.11	-0.19	-0.32	-0.32
GWA	0.01	-0.12	0.02	-0.02	-0.30	-0.10	-0.10	-0.21	0.27	0.35	0.03	0.83	0.75	0.09	0.05	-0.03
	0.06	-0.45	0.34	-0.18	-0.23	0.07	0.11	0.01	0.10	0.56	0.02	0.80	0.79	-0.14	-0.06	-0.14
	-0.08	-0.64	0.06	-0.32	0.18	0.00	0.01	-0.01	0.07	0.41	-0.01	0.83	0.79	-0.12	0.09	-0.13
CWA	0.09	0.05	-0.03	0.09	-0.26	-0.10	-0.10	-0.17	0.21	0.37	0.26	0.78	0.80	0.06	-0.02	-0.11
	0.08	-0.41	0.35	-0.14	-0.16	0.09	0.12	0.06	0.03	0.62	0.22	0.72	0.77	-0.20	-0.08	-0.17
	-0.04	-0.64	0.00	-0.20	0.25	0.01	0.02	0.00	0.06	0.39	0.32	0.74	0.81	-0.19	-0.22	-0.25
LG	-0.05	0.10	0.01	0.19	0.41	0.45	0.43	0.42	-0.35	-0.10	0.04	-0.08	-0.04	0.68	-0.01	0.01
	-0.27	0.35	-0.60	-0.18	-0.21	-0.52	-0.52	-0.45	0.24	-0.20	-0.06	-0.23	-0.24	0.56	-0.49	-0.24
	-0.41	0.57	-0.46	-0.18	-0.11	-0.42	-0.44	-0.36	-0.01	-0.10	0.10	-0.09	-0.04	0.49	-0.45	-0.32
BUL	0.34	-0.23	0.29	0.05	0.01	0.15	0.14	0.03	0.08	-0.22	0.20	-0.01	0.09	-0.14	0.15	0.18
	0.25	-0.35	0.41	0.04	0.12	0.45	0.47	0.36	-0.14	0.03	-0.25	0.18	0.09	-0.37	0.71	0.56
	0.39	-0.36	0.31	-0.05	0.14	0.53	0.54	0.47	-0.12	-0.07	-0.47	0.02	-0.15	-0.18	0.93	0.82
RES	0.19	-0.21	0.18	-0.02	0.02	0.03	0.02	-0.03	0.06	-0.20	0.06	-0.10	-0.06	-0.21	0.19	0.32
	0.14	-0.24	0.14	0.01	0.04	0.30	0.32	0.24	-0.07	-0.14	-0.34	0.15	0.05	-0.11	0.60	0.72
	0.23	-0.41	0.00	-0.32	-0.04	0.21	0.21	0.15	0.09	-0.13	-0.41	0.17	0.02	-0.08	0.84	0.85

Correlations are arranged in descending order of shearings 1, 2 and 3. (Third shearing ewes only).

For shearings 1 and 2: $r>0.236$ ($p<0.05$), $r>0.307$ ($p<0.01$). For shearing 3: $r>0.327$ ($p<0.05$), $r>0.419$ ($p<0.01$)

Sh = shoulder, Av. = Average of the fleece

Table A4. Correlations between mid-side wool traits and fleece average at shearings 1, 2 and 3 in Flock B (pooled over sexes)

MS → Av ↓	KS	HG	MI	CCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS	0.74	-0.06	0.11	0.24	-0.02	0.11	0.10	0.06	-0.01	0.06	0.22	0.04	0.11	-0.06	0.12	0.08
	0.84	-0.22	0.19	0.05	0.03	0.34	0.39	0.28	0.10	-0.10	0.18	-0.13	-0.02	-0.14	0.29	0.23
	0.87	-0.19	-0.06	-0.29	-0.14	0.08	0.09	-0.10	0.29	-0.46	-0.08	-0.12	-0.14	-0.31	0.37	0.42
HG	-0.01	0.82	-0.20	0.39	-0.01	-0.10	-0.11	-0.04	-0.05	0.12	0.35	0.01	0.13	0.05	-0.21	-0.19
	-0.23	0.73	-0.54	-0.06	0.10	-0.23	-0.27	-0.15	-0.17	-0.08	0.07	-0.38	-0.32	0.43	-0.62	-0.52
	-0.05	0.75	-0.28	0.43	0.30	-0.27	-0.29	0.02	-0.36	-0.04	0.14	-0.55	-0.48	0.47	-0.49	-0.52
MI	0.04	-0.31	0.96	-0.13	0.02	0.22	0.24	0.12	0.01	0.15	0.04	0.00	0.01	0.07	0.57	0.55
	0.32	-0.53	0.86	0.18	-0.01	0.49	0.54	0.50	-0.15	0.38	0.09	0.32	0.33	-0.59	0.53	0.35
	0.09	-0.33	0.75	0.07	0.01	0.55	0.56	0.34	0.01	0.12	-0.17	0.07	0.01	-0.32	0.35	0.13
CCG	0.24	0.52	-0.14	0.86	0.39	0.22	0.19	0.32	-0.42	0.03	0.18	0.04	0.10	0.18	-0.14	-0.08
	0.11	0.16	0.17	0.53	0.24	0.29	0.24	0.35	-0.34	-0.06	0.20	-0.13	-0.07	-0.03	-0.02	-0.05
	-0.09	0.32	-0.03	0.80	0.42	0.34	0.32	0.47	-0.50	0.07	0.34	-0.45	-0.31	0.42	-0.16	-0.27
SCG	-0.02	0.09	-0.03	0.27	0.86	0.63	0.61	0.77	-0.82	-0.06	-0.05	-0.21	-0.21	0.37	-0.07	-0.02
	0.24	0.21	0.07	0.21	0.72	0.49	0.34	0.55	-0.56	-0.08	0.23	-0.44	-0.29	-0.13	0.11	0.09
	-0.12	0.37	0.03	0.51	0.88	0.54	0.51	0.77	-0.83	0.33	-0.01	-0.16	-0.16	0.58	-0.07	-0.17
X	0.12	-0.03	0.08	0.14	0.73	0.75	0.74	0.77	-0.69	0.01	-0.01	-0.09	-0.12	0.35	0.00	0.03
	0.46	-0.04	0.39	0.26	0.43	0.78	0.66	0.79	-0.52	0.01	0.20	-0.21	-0.12	-0.28	0.34	0.27
	0.16	-0.08	0.30	0.37	0.60	0.91	0.90	0.87	-0.57	0.19	-0.11	-0.08	-0.11	0.27	0.42	0.24
Y	0.06	-0.05	0.09	0.11	0.71	0.74	0.74	0.76	-0.68	0.03	-0.11	-0.08	-0.12	0.34	0.02	0.05
	0.49	-0.08	0.42	0.26	0.39	0.78	0.74	0.79	-0.41	0.01	0.19	-0.15	-0.08	-0.29	0.33	0.33
	0.17	-0.09	0.30	0.36	0.59	0.91	0.91	0.87	-0.56	0.18	-0.12	-0.06	-0.10	0.25	0.43	0.26
Z	0.06	0.05	-0.05	0.26	0.78	0.65	0.64	0.75	-0.79	-0.03	-0.02	-0.14	-0.13	0.38	-0.04	-0.01
	0.43	0.03	0.35	0.27	0.42	0.72	0.60	0.77	-0.61	0.04	0.26	-0.23	-0.10	-0.28	0.26	0.22
	0.02	0.11	0.21	0.49	0.73	0.80	0.78	0.91	-0.78	0.30	-0.09	-0.19	-0.21	0.50	0.17	0.00
Y-Z	0.04	-0.16	0.24	-0.40	-0.71	-0.41	-0.38	-0.60	0.77	0.11	-0.10	0.19	0.13	-0.35	0.10	0.10
	-0.20	-0.23	-0.11	-0.23	-0.38	-0.43	-0.22	-0.55	0.75	-0.08	-0.33	0.27	0.11	0.21	-0.08	0.04
	0.18	-0.35	-0.05	-0.55	-0.74	-0.46	-0.43	-0.75	0.89	-0.38	0.03	0.31	0.31	-0.71	0.22	0.33
STL	0.06	0.03	0.14	-0.14	-0.25	-0.18	-0.18	-0.23	0.25	0.82	0.20	0.43	0.46	-0.09	-0.01	-0.02
	-0.10	-0.11	0.37	-0.03	-0.20	0.06	0.03	0.10	-0.16	0.91	0.15	0.41	0.43	-0.28	0.07	-0.03
	-0.63	-0.11	0.20	0.05	0.45	0.28	0.26	0.41	-0.46	0.92	0.02	0.43	0.41	0.28	-0.12	-0.17
YLD	0.17	0.33	-0.01	0.30	-0.11	-0.18	-0.19	-0.15	0.07	0.22	0.70	-0.01	0.24	-0.17	-0.01	-0.03
	0.07	-0.05	0.05	0.33	0.02	0.11	0.10	0.16	-0.19	0.09	0.81	-0.05	0.26	0.07	-0.14	-0.01
	-0.05	0.33	-0.29	0.33	0.05	-0.18	-0.18	-0.11	0.00	0.04	0.91	-0.12	0.19	0.06	-0.30	-0.22
GWA	0.26	-0.08	-0.01	-0.03	-0.26	-0.14	-0.14	-0.21	0.26	0.40	0.11	0.78	0.74	0.01	-0.03	-0.04
	-0.12	-0.30	0.35	0.04	-0.39	-0.05	0.08	-0.06	0.14	0.44	-0.08	0.88	0.78	-0.24	0.09	0.18
	-0.18	-0.11	0.08	-0.25	0.03	0.07	0.07	0.08	-0.07	0.25	-0.13	0.81	0.73	-0.04	-0.03	0.08
CWA	0.31	0.05	-0.02	0.11	-0.29	-0.18	-0.19	-0.24	0.27	0.42	0.31	0.70	0.74	-0.01	-0.03	-0.04
	-0.09	-0.30	0.38	0.11	-0.38	-0.02	0.07	-0.01	0.09	0.49	0.14	0.86	0.84	-0.23	0.05	0.17
	-0.20	0.01	-0.03	-0.11	0.06	0.02	0.02	0.06	-0.08	0.26	0.20	0.75	0.78	0.00	-0.15	-0.01
LG	-0.03	0.11	-0.04	0.07	0.33	0.27	0.25	0.32	-0.36	0.08	0.06	-0.07	-0.02	0.60	0.02	-0.01
	-0.42	0.42	-0.59	-0.29	-0.09	-0.40	-0.39	-0.39	0.12	-0.18	-0.20	-0.17	-0.25	0.66	-0.62	-0.46
	-0.31	0.43	-0.22	0.32	0.21	-0.30	-0.33	0.03	-0.43	0.11	-0.15	-0.37	-0.39	0.70	-0.55	-0.50
BUL	0.22	-0.08	0.28	0.25	-0.01	0.12	0.13	0.07	0.03	-0.26	-0.06	-0.18	-0.19	0.04	0.59	0.56
	0.38	-0.40	0.40	0.10	0.14	0.40	0.36	0.35	-0.08	0.01	-0.08	-0.06	-0.06	-0.49	0.85	0.62
	0.42	-0.48	0.04	-0.32	-0.11	0.34	0.37	0.03	0.36	-0.18	-0.16	0.15	0.09	-0.38	0.93	0.86
RES	0.10	-0.09	0.18	0.14	-0.03	0.05	0.06	0.03	0.02	-0.19	-0.11	-0.19	-0.21	0.08	0.54	0.59
	0.29	-0.33	0.22	0.08	0.12	0.30	0.30	0.24	0.06	-0.14	-0.06	-0.09	-0.11	-0.35	0.65	0.66
	0.33	-0.43	-0.13	-0.46	-0.19	0.15	0.18	-0.11	0.40	-0.18	-0.17	0.27	0.21	-0.32	0.76	0.86

Correlations are arranged in descending order of shearings 1, 2 and 3. (Third shearing ewes only.)
For shearings 1 and 2: $r>0.236$ ($p<0.05$), $r>0.307$ ($p<0.01$). For shearing 3: $r>0.327$ ($p<0.05$), $r>0.419$ ($p<0.01$)
MS = Mid-side, Av. = Average of the fleece

Table A5. Correlations of the average of the third fleece with various wool traits estimated from shoulder and mid-side and the all positions average of the first fleece in Flock A, pooled over sexes

Av3 → FL1 ↓	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS	0.20	-0.39	0.09	0.04	0.09	0.01	0.01	0.06	-0.10	-0.09	0.11	-0.08	-0.05	-0.01	0.15	0.12
	0.17	-0.20	0.12	0.04	-0.08	0.12	0.11	0.04	0.07	0.03	-0.03	-0.09	-0.10	-0.44	0.27	0.26
	0.29	-0.26	0.12	0.07	0.06	-0.04	-0.03	0.01	-0.04	-0.03	-0.09	-0.12	-0.15	-0.29	0.37	0.35
HG	-0.25	0.27	0.14	-0.02	-0.19	-0.02	-0.02	-0.07	0.16	0.06	0.08	0.33	0.30	0.14	-0.35	-0.33
	-0.25	0.35	0.16	0.02	-0.03	0.05	0.05	0.01	0.04	0.10	-0.15	0.08	0.02	-0.05	-0.13	-0.13
	-0.32	0.44	0.17	-0.01	-0.21	-0.05	-0.05	-0.11	0.16	0.24	0.08	0.39	0.35	0.12	-0.44	-0.38
MI	-0.04	0.05	0.53	0.27	0.32	0.50	0.49	0.50	-0.38	0.01	0.05	-0.21	-0.18	-0.35	0.11	0.02
	0.04	-0.05	0.41	0.23	0.13	0.51	0.49	0.37	-0.09	0.06	0.27	-0.17	-0.05	-0.24	-0.03	-0.12
	-0.05	0.02	0.55	0.26	0.24	0.56	0.54	0.45	-0.20	0.03	0.14	-0.18	0.11	-0.35	-0.04	-0.14
GCG	0.21	0.25	-0.06	0.06	0.17	0.04	-0.04	0.07	-0.17	-0.21	-0.24	0.02	-0.07	0.04	0.12	0.12
	0.08	0.05	-0.06	0.01	0.09	-0.12	-0.12	-0.02	-0.11	-0.01	-0.15	0.07	-0.01	0.04	0.04	0.01
	0.23	0.17	-0.02	0.18	0.13	0.01	-0.01	0.11	-0.22	-0.04	-0.03	0.01	0.16	0.16	0.03	0.04
SCG	0.39	0.04	-0.21	-0.04	0.42	0.08	0.07	0.24	-0.39	-0.41	-0.26	-0.16	-0.22	0.10	0.33	0.23
	0.02	0.11	0.24	0.22	0.35	0.35	0.34	0.41	-0.35	-0.08	-0.07	-0.15	-0.16	-0.19	0.08	-0.05
	0.24	0.01	0.07	0.07	0.35	0.20	0.19	0.29	-0.35	-0.23	-0.17	-0.07	-0.12	-0.09	0.23	0.14
X	0.23	-0.03	-0.04	0.17	0.18	0.20	0.20	0.21	-0.16	-0.40	-0.19	-0.15	-0.17	-0.09	0.41	0.43
	0.12	-0.07	0.28	0.11	0.15	0.35	0.35	0.27	-0.11	-0.27	-0.07	-0.15	-0.15	-0.27	0.28	0.22
	0.17	0.01	0.20	0.22	0.16	0.28	0.28	0.24	-0.15	-0.26	-0.12	-0.04	-0.08	-0.20	0.29	0.26
Y	0.24	-0.04	-0.03	0.16	0.16	0.17	0.18	0.20	-0.15	-0.41	-0.22	-0.16	-0.19	-0.08	0.40	0.42
	0.09	-0.11	0.28	0.12	0.13	0.33	0.33	0.25	-0.10	-0.29	-0.09	-0.13	-0.14	-0.31	0.32	0.25
	0.17	-0.01	0.19	0.22	0.15	0.24	0.24	0.23	-0.14	-0.27	-0.13	-0.05	-0.08	-0.19	0.31	0.28
Z	0.39	-0.02	-0.05	0.12	0.39	0.25	0.24	0.35	-0.36	-0.45	-0.26	-0.25	-0.28	-0.11	0.45	0.42
	0.18	-0.06	0.25	0.03	0.29	0.37	0.37	0.35	-0.24	-0.31	-0.10	-0.19	-0.19	-0.28	0.30	0.23
	0.25	0.02	0.17	0.17	0.31	0.33	0.32	0.35	-0.28	-0.32	-0.15	-0.08	-0.12	-0.17	0.32	0.26
Y-Z	-0.46	-0.03	0.06	0.01	-0.56	-0.28	-0.26	-0.44	0.55	0.38	0.24	0.29	0.32	0.10	-0.35	-0.26
	-0.25	-0.06	-0.05	0.15	-0.43	-0.27	-0.26	-0.34	0.35	0.23	0.12	0.18	0.22	0.11	-0.17	-0.09
	-0.32	-0.11	-0.02	0.04	-0.57	-0.35	-0.04	-0.45	0.49	0.33	0.14	0.10	0.15	0.04	-0.18	-0.06
STL	-0.12	0.21	-0.07	0.11	-0.06	0.03	0.04	-0.01	0.07	-0.07	-0.21	-0.08	-0.13	-0.15	0.22	0.23
	0.01	-0.05	-0.15	0.07	-0.04	-0.02	0.00	-0.03	0.08	-0.26	-0.22	-0.20	-0.23	-0.11	0.36	0.38
	-0.02	-0.04	-0.02	0.08	-0.11	0.03	0.05	-0.03	0.12	-0.16	-0.13	-0.18	-0.18	-0.17	0.31	0.31
YLD	0.13	0.07	0.08	0.19	-0.02	0.17	0.16	0.17	-0.14	0.23	0.42	0.18	0.28	0.15	-0.39	-0.41
	0.09	-0.07	0.11	-0.21	-0.03	-0.01	-0.01	-0.03	0.06	0.36	0.14	0.08	0.12	-0.07	-0.31	-0.35
	0.04	-0.06	0.30	0.05	-0.08	0.24	0.24	0.16	-0.01	0.45	0.44	0.15	0.26	-0.11	-0.45	-0.50
GWA	-0.18	0.04	-0.08	-0.06	-0.35	-0.13	-0.12	-0.22	0.28	-0.22	-0.03	0.02	0.02	-0.07	0.19	0.25
	0.07	-0.02	-0.23	-0.13	-0.09	-0.09	-0.06	-0.12	0.17	-0.41	-0.24	-0.07	-0.14	-0.04	0.37	0.45
	-0.08	0.01	-0.18	-0.12	-0.24	-0.13	-0.11	-0.21	0.27	-0.35	-0.17	-0.04	-0.08	-0.07	0.34	0.41
CWA	-0.18	0.06	-0.06	-0.01	-0.35	-0.10	-0.09	-0.18	0.24	-0.16	0.08	0.06	0.09	-0.03	0.08	0.16
	0.11	-0.02	-0.01	-0.17	-0.11	-0.10	-0.07	-0.13	0.18	-0.33	-0.22	-0.05	-0.11	-0.03	0.27	0.37
	-0.06	0.02	-0.17	-0.12	-0.27	-0.12	-0.10	-0.20	0.27	-0.30	-0.10	0.01	-0.02	-0.06	0.25	0.34
LG	0.03	0.17	-0.02	0.11	0.07	-0.01	-0.01	0.07	-0.14	0.03	-0.05	0.22	0.17	0.11	-0.01	0.02
	-0.14	0.07	-0.03	-0.08	-0.09	-0.05	-0.03	-0.09	0.14	0.01	-0.06	0.12	0.10	-0.11	0.08	0.13
	-0.05	0.03	0.13	0.17	-0.04	-0.06	-0.06	0.04	-0.13	0.06	-0.06	0.19	0.14	0.10	0.05	0.14
BUL	0.19	-0.60	0.20	-0.12	0.21	0.31	0.31	0.27	-0.15	0.00	-0.09	-0.38	-0.34	-0.42	0.35	0.22
	0.13	-0.52	0.16	-0.10	0.15	0.19	0.19	0.17	-0.09	-0.07	-0.09	-0.21	-0.20	-0.34	0.29	0.15
	0.24	-0.58	0.24	-0.11	0.23	0.39	0.39	0.20	-0.13	-0.05	-0.12	-0.26	-0.26	-0.42	0.31	0.21
RES	0.25	-0.42	0.04	-0.09	0.26	0.14	0.16	0.24	-0.29	-0.05	-0.18	-0.32	-0.32	-0.18	0.33	0.24
	0.21	-0.32	-0.12	-0.13	0.23	0.04	0.05	0.16	-0.26	-0.24	-0.09	-0.27	-0.26	0.01	0.25	0.21
	0.06	-0.45	0.01	-0.12	0.32	0.10	0.11	0.21	-0.27	-0.19	-0.17	-0.29	-0.30	-0.16	0.27	0.22

Correlations are arranged in descending order of shoulder, mid-side and the all-positions average of the first fleece.
$r>0.271$ ($p<0.05$), $r>0.351$ ($p<0.01$).
Av3 = average of shearing 3. FL1 = first shearing.

Table A6. Correlations of the average of the third fleece with various wool traits estimated from shoulder and mid-side and the all positions average of the first fleece in Flock B, pooled over sexes.

Av3 → FL1 ↓	KS	HG	MI	GCG	SCG	X	Y	Z	Y-Z	STL	YLD	GWA	CWA	LG	BUL	RES
KS	0.25	-0.17	0.29	0.14	0.08	0.24	0.24	0.16	-0.02	-0.01	0.32	-0.16	-0.05	-0.47	0.33	0.15
	0.19	-0.31	0.30	0.01	0.00	0.21	0.22	0.13	0.03	0.07	-0.16	0.07	0.00	-0.39	0.32	0.15
	0.33	-0.24	0.37	0.01	0.07	0.19	0.20	0.09	0.07	0.02	0.12	0.04	0.07	-0.54	0.37	0.19
HG	0.17	-0.07	0.00	-0.03	0.00	0.02	0.03	0.03	-0.02	-0.05	0.22	0.22	0.29	-0.12	-0.14	-0.14
	-0.06	0.11	-0.04	0.13	0.07	0.13	0.12	0.15	-0.15	-0.08	0.19	0.11	0.17	0.06	-0.17	-0.13
	-0.01	0.14	-0.04	0.15	0.09	0.03	0.02	0.08	-0.14	-0.05	0.34	0.11	0.23	0.04	-0.27	-0.30
MI	0.11	-0.35	0.66	-0.04	0.20	0.48	0.49	0.42	-0.23	0.31	-0.27	0.10	0.18	-0.27	0.15	-0.02
	0.10	-0.48	0.52	-0.06	0.08	0.35	0.35	0.26	-0.08	0.30	-0.14	0.12	0.07	-0.49	0.32	0.21
	0.20	-0.48	0.68	-0.01	0.19	0.51	0.53	0.38	-0.11	0.24	-0.20	0.13	0.06	-0.51	0.37	0.16
GCG	0.02	0.07	0.05	0.11	0.02	0.03	0.03	0.03	-0.02	0.06	0.51	0.11	0.27	-0.08	-0.03	-0.09
	0.08	0.11	0.16	0.27	0.06	0.21	0.21	0.17	-0.07	-0.12	0.31	-0.07	0.04	-0.05	0.06	-0.06
	0.08	0.06	0.18	0.24	0.10	0.22	0.21	0.18	-0.10	-0.01	0.34	-0.04	0.07	-0.08	0.06	-0.07
SCG	0.08	0.26	0.02	0.37	0.31	0.28	0.27	0.25	-0.17	-0.06	0.39	-0.21	-0.08	-0.14	0.12	-0.04
	0.12	0.24	-0.13	0.26	0.07	0.11	0.11	0.07	-0.01	-0.17	0.21	-0.26	-0.19	0.02	0.08	0.04
	0.14	0.32	-0.13	0.38	0.19	0.16	0.16	0.15	-0.09	-0.19	0.34	-0.25	-0.13	-0.05	0.01	-0.09
X	0.34	-0.01	0.24	0.29	0.38	0.43	0.44	0.36	-0.18	-0.11	0.17	-0.10	-0.04	-0.33	0.30	0.09
	0.26	0.08	0.04	0.27	0.21	0.21	0.22	0.19	-0.09	-0.13	0.17	-0.17	-0.11	-0.11	0.12	0.08
	0.27	0.04	0.14	0.29	0.20	0.25	0.26	0.20	-0.08	-0.18	0.14	-0.23	-0.19	-0.26	0.15	-0.02
Y	0.35	-0.01	0.23	0.28	0.38	0.42	0.43	0.36	-0.18	-0.12	0.16	-0.09	-0.03	-0.33	0.30	0.09
	0.24	0.08	0.05	0.26	0.21	0.21	0.22	0.19	-0.09	-0.15	0.16	-0.18	-0.12	-0.10	0.12	0.07
	0.27	0.04	0.12	0.28	0.20	0.24	0.25	0.19	-0.07	-0.20	0.13	-0.23	-0.19	-0.25	0.15	-0.01
Z	0.22	0.20	0.14	0.38	0.35	0.35	0.35	0.31	-0.18	-0.11	0.32	-0.24	-0.12	-0.25	0.14	-0.06
	0.26	0.16	-0.01	0.31	0.18	0.23	0.23	0.20	-0.10	-0.15	0.25	-0.23	-0.14	-0.06	0.13	0.06
	0.24	0.16	0.05	0.33	0.21	0.23	0.24	0.20	-0.11	-0.18	0.25	-0.29	-0.20	-0.20	0.09	-0.07
Y-Z	-0.05	-0.34	-0.02	-0.38	0.25	-0.21	-0.20	-0.19	0.13	0.08	-0.40	0.32	0.18	0.13	0.04	0.18
	-0.25	-0.22	0.07	-0.31	-0.13	-0.21	-0.21	-0.18	0.10	0.13	-0.31	0.25	0.15	0.02	-0.11	-0.04
	-0.16	-0.30	0.05	-0.37	-0.21	-0.20	-0.19	-0.19	0.14	0.13	-0.38	0.33	0.20	0.09	0.01	0.14
STL	-0.26	-0.06	0.04	-0.01	0.20	0.03	0.03	0.11	-0.18	0.50	-0.19	0.27	0.21	0.25	-0.19	-0.09
	0.01	0.25	-0.16	0.10	0.33	0.03	0.02	0.14	-0.26	0.33	-0.05	0.02	0.00	0.13	-0.10	-0.08
	-0.22	0.00	0.06	0.04	0.23	0.05	0.05	0.13	-0.21	0.53	-0.13	0.18	0.13	0.18	-0.16	-0.13
YLD	-0.02	0.05	0.18	0.09	0.29	0.29	0.28	0.30	-0.24	0.12	0.31	-0.03	0.09	0.00	0.01	-0.07
	-0.09	0.02	0.27	0.17	0.30	0.16	0.16	0.22	-0.25	0.29	0.22	0.16	0.24	-0.15	-0.21	-0.39
	-0.07	-0.01	0.15	0.11	0.23	0.18	0.18	0.18	-0.14	0.23	0.37	0.13	0.26	-0.17	-0.08	-0.16
GWA	0.27	-0.12	0.23	-0.24	0.05	0.18	0.19	0.12	0.00	-0.04	-0.51	0.13	-0.04	-0.02	0.18	0.16
	0.04	-0.13	-0.03	-0.29	-0.09	-0.13	-0.12	-0.11	0.07	0.12	-0.38	0.30	0.15	-0.02	-0.12	-0.04
	0.18	-0.19	0.30	-0.21	0.09	0.17	0.18	0.12	0.00	0.06	-0.56	0.20	0.00	-0.03	0.15	0.10
CWA	0.28	-0.09	0.25	-0.23	0.13	0.25	0.25	0.19	-0.07	0.01	-0.40	0.14	0.00	-0.02	0.17	0.14
	0.02	-0.12	0.07	-0.23	0.01	-0.06	-0.06	-0.02	-0.03	0.22	-0.30	0.33	0.22	-0.07	-0.18	-0.16
	0.16	-0.19	0.32	-0.18	0.16	0.23	0.24	0.18	-0.05	0.14	-0.40	0.25	0.11	-0.09	0.12	0.06
LG	0.22	0.09	-0.18	-0.02	0.35	0.14	0.15	0.19	-0.20	0.05	-0.09	0.11	0.07	-0.08	0.17	0.13
	-0.02	0.09	0.07	0.25	0.37	0.36	0.37	0.38	-0.31	0.01	-0.02	-0.05	-0.06	-0.08	0.17	0.03
	0.03	0.06	0.08	0.12	0.45	0.33	0.34	0.40	-0.38	0.27	0.03	0.05	0.05	-0.12	0.08	-0.07
BUL	-0.02	-0.12	0.15	-0.07	0.01	0.16	0.16	0.12	-0.05	-0.17	-0.09	-0.10	-0.12	-0.09	0.22	0.13
	0.12	-0.28	0.20	-0.07	-0.10	0.29	0.30	0.15	0.07	0.04	-0.09	-0.19	-0.23	-0.25	0.63	0.60
	0.18	-0.29	0.12	-0.15	-0.05	0.30	0.31	0.18	0.03	-0.15	-0.18	-0.10	-0.16	-0.24	0.68	0.66
RES	-0.11	-0.01	-0.08	-0.02	0.06	0.03	0.03	0.00	0.04	-0.08	-0.02	-0.06	-0.07	-0.12	0.23	0.24
	0.16	-0.14	0.04	0.03	-0.02	0.30	0.30	0.21	-0.05	-0.04	-0.17	-0.18	-0.24	-0.05	0.46	0.46
	0.04	-0.10	-0.18	-0.12	-0.05	0.09	0.10	0.02	0.08	-0.14	-0.13	-0.13	-0.18	-0.10	0.56	0.64

Correlations are arranged in descending order of shoulder, mid-side and the all-positions average of the first fleece.
r>0.236 (p<0.05), r>0.307 (p<0.01).
Av3 = average of shearing 3., FL1 = first shearing (Third shearing ewes only).

REFERENCES

ACHARYA, R.M.; MALHI, R.S.; ARORA, C.L. (1972). Studies on sampling procedure for assessing wool quality in Indian sheep: Determination of body region for sampling. A preliminary note. *Indian J. Anim. Sci. 42:* 1043-1044.

ALEXANDER, G. (1958). Heat production of newborn lambs in relation to type of birthcoat. *Proc. Aust. Soc. Anim. Prod. 2:* 10-14.

ALI, M.A.; WHITELEY, K.J.; CHAUDRI, M.A. (1971). II. The influence of fibre characteristics on the tactile appraisal of loose wool. *J. Text. Inst. 62:* T375-381.

ANDERSON, S.L.; CLEGG, D.G. (1963). Physical test methods for carpets. *Text. Inst. Ind. 1 (2):* 6-8.

ASTM. (1958). Tentative method of test for extractable matter in oven dried wool. *American Society for Testing Materials.* D1574-58T, 1958.

BAGIROV, Ju.D. (1968). Selection for fleece uniformity at an early age. *Anim. Breed. Abstr. 37:* No. 477.

BEDFORD, J.; ROSS, D.A.; CARNABY, G.A.; LAPPAGE, J. (1977): WRONZ fibre bulkometer "Instruction Manual". WRONZ report.

BELL, A.K. (1981) The responsibility and reports of working groups. *Proc. Carpet Wool Workshop,*Burnie, Tasmania; 203-214.

BIGHAM, M.L. (1975). Guidelines for wool production in New Zealand. *Sheepfarming Annual, 1975.*

BIGHAM, M.L.; MEYER, H.H.; SMEATON, J.E. (1983a). The heritability of loose wool bulk and colour traits and their genetic and phenotypic correlations with other wool traits. *Proc. N.Z. Soc. Anim. Prod.* *43*: 83-85.

BIGHAM, M.L.; SUMNER, R.M.W.; HAWKER, H.; FITZGERALD, J.M. (1983b). Fleece tenderness, a review. *Proc. N.Z. Soc. Anim. Prod.* *43*: 73-78.

BIGHAM, M.L.; SUMNER, R.M.W.; COX, N.R. (1984a). The measurement and sources of variation of loose wool bulk in Romney, Coopworth and Perendale breeds. *N.Z. J. Exp. Agric.,* *12*: 23-28.

BIGHAM, M.L.; SUMNER, R.M.W.; COX, N.R. (1984b). Sources of variation and experimental design criteria for wool colour measurement applied to Romney, Coopworth and Perendale flocks. *N.Z. J. Exp. Agric.* *12*: 231-236.

BIGHAM, M.L.; SUMNER, R.M.W.; CLARKE, J.N.; JOHNSON, D.L. (1985). Inheritance of loose wool bulk in Romney and Perendale sheep. *Proc. N.Z. Soc. Anim. Prod.* *45*: 213-215.

BLAIR, H.T. (1981). *Response to selection for open face and greasy fleece weight in Romney sheep.* Ph.D. Thesis, Massey University, New Zealand.

BORUM, K. (1954). Hair pattern and hair succession in the Albino mouse. *Acta Path.* *34*: 521-541.

BRATT, R.L. (1965). The effect of staple strength on worsted processing. III. Fibre length distribution and spinning. *J. Text. Inst.* *56*: T62-72.

BRATT, R.L.; ROSS, D.A.; STORY, L.F. (1964). The effect of staple strength on worsted processing. II. Carding and combing of 58/60s. *J. Text. Inst.* *55*: T165-174.

BURNS, M. (1955). Observations on Merino X Herdwick hybrid sheep with special reference to the fleece. *J. Agric. Sci., Camb.* *46*: 389-406.

BURNS, M. (1966). Merino birthcoat fibre types and their follicular origin. *J. Agric. Sci., Camb.* *66*: 155-173.

BURNS, M. (1967a). The Katsina wool project. I. The coat and skin histology of some northern Nigerian hair sheep and their Merino crosses. *Trop. Agric., Trin.* *44*: 173-192.

BURNS, M. (1967b). The Katsina wool project. II. Coat and skin data from 3/4-Merino and Wensleydale crosses. *Trop. Agric. Trin.* *44*: 253-274.

BURNS, M. (1972). Effects of ova transfer on the birthcoats of lambs. *J. Agric. Sci., Camb.* *78*: 1-6.

BURNS, M.; RYDER, M.L. (1974). Effect of egg transfer on the skin follicles and birthcoats of the Finnish Landrace and Soay lambs. *J. Agric. Sci., Camb.* *82*: 209-216.

BURNS, R.H.; JOHNSTON, A.; CHEN, W.C. (1940). The improvement of Chinese and other carpet wools. *J. Text. Inst.* *31*: T37-48.

CARNABY, G.A. (1978). Carpet wools and carpets: A summary of WRONZ research. In *Carpet wools - carpet manufacture*. (Ed. Story, L.F.) WRONZ, Christchurch, New Zealand: 43-50.

CARNABY, G.A. (1979). Bulk and medullation properties of carpet wools. *Wool* *5*: 29-32.

CARNABY, G.A.; GROSBERG, P. (1976). The tensil behaviour of staple-fibre yarns at small extensions. *J. Text. Inst.* *76*: T299-308.

CARNABY, G.A.; ELLIOTT, K.H. (1980). Bulk: a wool trait of importance to the carpet industry. *Proc. N.Z. Soc. Anim. Prod.* *40*: 196-204.

CARNABY, G.A.; ROSS, D.A.; ELLIOTT, K.H. (1984). The effect of fibre and processing variables on yarn bulk and related properties of wool carpets. *J. Text. Inst.* *75*: 1-16.

CARTER, H.B.; TIBBITS, J.P. (1959). Postnatal growth changes in the skin follicle population of the New Zealand Romney and *N*-type sheep. *J. Agric. Sci., Camb.* *52*: 106-116.

CHAPMAN, R.E.; YOUNG, S.S.Y. (1957). A study of wool production per unit area of skin in Australian Merino sheep. *Aust. J. Agric. Res.* *8*: 723-732.

CHAPMAN, R.E.; WHEELER, J.L. (1963). Dyebanding: a technique for fleece growth studies. *Aust. J. Sci.* *26*: 53-54.

CHASE, H.B.; SLIVER, A.F. (1969). The biology of hair growth. In *The biological basis of medicine*. (Ed. Bittar, E.E.) Academic Press, London, 6: 3-19.

CHAUDRI, M.A.; WHITELEY, K.J. (1968). The influence of natural variations in fibre properties on the bulk compression of wool. *Text. Res. J.* *38*: 897-906.

CHOPRA, S.C. (1978). *Genotype-environment interaction and genetic parameters in New Zealand Romney sheep.* Ph.D. Thesis, Massey University, New Zealand.

CLARK, M.J.; WHITELEY, K.J. (1978). Some aspects of the measurement of colour in raw wool. *J. Text. Inst. 69*: T121-130.

COCKREM, F. (1962). A relationship between skin temperature and amount of wool grown on various positions on the New Zealand Romney Marsh sheep. *Nature 196*: 560-561.

COCKREM, F. (1963). Body growth and fleece development in the New Zealand Romney *N*-type sheep. *Anim. Breed. Abstr. 31*: 445-453.

COCKREM, F.; WICKHAM, G.A. (1960). Some preliminary observations on factors affecting the temperature at the skin surface of the New Zealand Romney sheep. *N.Z. J. Agric. Res., 3*: 1015-1026.

COLLINS, J.D.; CHAIKIN, M. (1968). Structural and non-structural effects in the observed stress-strain curve for wet wool fibres. *J. Text. Inst. 59*: T379-400.

DERBYSHIRE, M.B. (1975). Skin follicle development in Cheviot and Dorset Horn cross foetuses. *J. Agric. Sci., Camb. 84*: 401-406.

DESHPANDE, A.K. (1948). *Studies on the biology of the fleece of the Scottish Mountain Blackface lamb.* Ph.D. Thesis, Leeds University, U.K.

DONEY, J.M. (1959). Variation in fibre and staple length over the body of the sheep. *Aust. J. Agric. Res. 10*: 299-304.

DONEY, J.M. (1963). The fleece of the Scottish Blackface sheep. III. The relative importance of the fleece components. *J. Agric. Sci., Camb. 61*: 45-53.

DOWNES, J.G. (1975). Characteristics of greasy wool, their measurement and significance in manufacture. *Proc. V Intern. Wool Text. Res. Conf., Aachen 4*: 13-23.

DRY, F.W. (1926). The coat of the mouse (*mus musculus*). *J. Genet. 16*: 287-340.

DRY, F.W. (1935). Hairy fibres of the Romney sheep. *Collected reprints from N.Z. J. agric. 46 and 48.*

DRY, F.W. (1940). Recent work on the wool zoology of the New Zealand Romney. *N.Z. J. Sci. Technol. 22*: 209-220.

DRY, F.W. (1955a). Multifactorial inheritance of halo-hair abundance in New Zealand Romney sheep. *Aust. J. Agric. Res. 6*: 608-623.

DRY, F.W. (1955b). The dominant *N* gene in New Zealand Romney sheep. *Aust. J. Agric. Res.* *6*: 725-769.

DRY, F.W. (1955c). The recessive *N* gene in New Zealand Romney sheep. *Aust. J. Agric. Res.* *6*: 833-862.

DRY, F.W. (1965). Lamb fibre types. In *Biology of the skin and hair growth.* (Eds. Lyne, A.G.; Short, B.F.) Angus & Robertson, Sydney, Australia: 89-104.

DRY, F.W. (1975). *The architecture of lambs' coats, a speculative study.* Massey University, Palmerston North, New Zealand.

DRY, F.W.; McMAHON, P.R.; SUTHERLAND, J.A. (1940). A mendelian situation in the birthcoat of the New Zealand Romney lamb. *Nature* *145*: 390.

DRY, F.W.; FRASER, A.S. (1947). Mendelian inheritance in Romney sheep. *Proc. N.Z. Sci. Cong.*: 243.

DUERDEN, J.E. (1927). Evolution in the fleece of the sheep. *S. Afr. J. Sci.* *26*: 388-415.

DUERDEN, J.E. (1929). The zoology of the fleece of the sheep. *S. Afr. J. Sci.* *26*: 459-469.

DUERDEN, J.E.; SEALE, P.M. (1927). A new type of fibre in the Merino. *J. Text. Inst.* *18*: T265-273.

DUERDEN, J.E.; BOYD, E. (1930). The blackhead Persian. *S. Afr. Dept. Agric. Bull. No. 83.*

DUNLOP, J.I.; CARNABY, G.A.; ROSS, D.A. (1974). Bulk. I. The bulk of loose wool. *WRONZ Communication No. 28.*

EBLING, F.J. (1965). Comparative and evolutionary aspects of hair replacement. In *Comparative physiology and pathology of the skin.* (Eds. Rook. A.J.; Walton, G.S.) Blackwell Scientific Publications, Oxford, U.K.: 87-102.

ELGABBAS, H.M.H. (1978). *Birthcoat fibre type arrays and kemp succession in Barki sheep.* M. Agric. Sci. Thesis, Ain Shams University, Cairo, Egypt.

ELLIOTT, K.H. (1984). Price premiums for high-bulk Perendale ewes. *Proc. N.Z. Soc. Anim. Prod.* *44*: 41-44.

ELLIOTT, K.H.; CARNABY, G.A. (1980). Bulk. V. The effect of loose wool bulk on the bulk and other properties of carpet yarns. *WRONZ Communication No. 68.*

ELPHICK, B.L. (1932). A simple test for the detection of hairiness in the fleece. *Massey Agric. College Bull. 3.* New Zealand.

FRASER, A.S. (1951). Competition between skin follicles in sheep. *Nature 167*: 202-203.

FRASER, A.S. (1952a). Growth of wool fibres in sheep. *Aust. J. Agric. Res. 3*: 419-434.

FRASER, A.S. (1952b). Growth of the *N*-type fleece. *Aust. J. Agric. Res. 3*: 435-444.

FRASER, A.S. (1953). Factors in the genetic determination of fleece structure in sheep. *J. Genet. 51*: 222-236.

FRASER, A.S.; HAMADA, M.K.O. (1952). Observations on the birthcoats and skins of several breeds and crosses of British sheep. *Proc. Roy. Soc. Edinburgh B64*: 462-477.

FRASER, A.S.; SHORT, B.F. (1952). Competition between skin follicles in sheep. *Aust. J. Agric. Res. 3*: 445-452.

FRASER, A.S.; ROSS, J.M.; WRIGHT, G.M. (1954). Development of the fibre population in *N*-type sheep. *Aust. J. Agric. Res. 5*: 490-502.

FRASER, A.S.; SHORT, B.F. (1960). The biology of the fleece. *Anim. Res. Lab. Techn. Paper No. 3*. C.S.I.R.O., Australia.

GALLAGHER, J.R. (1971). An evaluation of Merino wool quality. III. The prediction of uniformity of fleece characters from fleece and skin characters of the birthcoat. *J. Agric. Sci., Camb. 76:* 211-215.

GALPIN, N. (1935). The pre-natal development of the coat of the New Zealand Romney lamb. *J. Agric. Sci., Camb. 25*: 344-350.

GALPIN, N. (1936). The occurrence of a britch-poll fibre type array gradient in the New Zealand Romney lamb. *Empire J. Exp. Agric. 4*: 116-128.

GILMOUR, A.R. (1981). *REG, a generalised linear models programme*. Dept. Animal Sci., Massey University, New Zealand. 107 pp.

GJEDREM, T. (1972). A study on the definition of the aggregate genotype in a selection index. *Acta Agric. Scand. 22*: 11-16.

GOOT, H. (1940). *Studies of the coat of the New Zealand Romney lamb*. M. Agric. Sci. Thesis, Massey University, New Zealand.

GOOT, H. (1945). Hairiness in wool. III. Growth of hairiness in New Zealand Romney Marsh lambs. *N.Z. J. Sci. Technol. 27*: 349-359.

GRANDSTAFF, J.O. (1942). Evaluation of fleece yield in the improvement of Navajo sheep. *J. Anim. Sci. 1*: 58-59.

GUIRGIS, R.A. (1967). Fibre type arrays and kemp succession in sheep. *J. Agric. Sci., Camb. 68*: 75-85.

GUIRGIS, R.A. (1977). Maternal influence on sheep production: a study of some birth traits of lambs. *J. Agric. Sci., Camb. 89*: 535-540.

GUIRGIS, R.A. (1979). Birthcoat fibre type arrays of lambs and some adult fleece traits. *J. Agric. Sci., Camb. 93*: 195-201.

GUIRGIS, R.A. (1980). Response to the use of Merino in improvement of coarse-wool Barki sheep: an analysis of some cross-bred wool traits. *J. Agric. Sci., Camb. 95*: 339-347.

GUIRGIS, R.A. (1982). Lamb birthcoat relationship to the adult fleece in Merino, coarse wool Barki and Merino X Barki sheep crosses. *J. Agric. Sci., Camb. 99*: 131-138.

GUIRGIS, R.A.; GALAL, E.S.E. (1972). The association between kemp and some vigour and wool characteristics in Barki and Merino Barki crosses. *J. Agric. Sci., Camb. 78*: 345-349.

GUIRGIS, R.A.; ELGABBAS, H.M.H.; GALAL, E.S.E.; GHONEIM, K.E. (1979a). Birthcoat-adult fleece relationship: a study of kemp succession in a coarse wool breed of sheep. *J. Agric. Sci., Camb. 92*: 427-436.

GUIRGIS, R.A.; KAZZAL, N.T.; ZAGHLOUL, A.M. (1979b). The study of kemp succession in the adult fleece of two coarse-wool breeds of sheep in relation to the birthcoat. *J. Agric. Sci., Camb. 93*: 531-540.

GUIRGIS, R.A.; AMIN, S.O.; GANEM, Y.S.; EL-SAYED, N.A. (1981a). Post-natal development, dimensions of the skin follicle population and birthcoat follicular origin in Barki and 3/8 Merino lambs. *J. Agric. Sci., Camb. 96*: 313-320.

GUIRGIS, R.A.; GHANEM, Y.S.; AMIN, S.O.; EL-GANAIENY, M.M. (1981b). Skin histology and birthcoat fibre-follicle relationships in Merino and 5/8 Merino lambs. *J. Agric. Sci., Camb. 96*: 151-158.

GUIRGIS, R.A.; AFIFI, E.A.; GALAL, E.S.E. (1982). Estimates of genetic and phenotypic parameters of some weight and fleece traits in a coarse wool breed of sheep. *J. Agric. Sci., Camb. 99*: 277-285.

HENDERSON, A.E. (1953). Fleece development and wool growth on the Romney lamb. *J. Agric. Sci., Camb. 43*: 12-53.

HOARE, J.L. (1974). The bleaching of crossbred wools: observations on the relationship between the price and colour of some scoured New Zealand crossbred wools. *J. Text. Inst. 65*: T402-408.

HOARE, J.L.; THOMPSON, B. (1974). Reflectance measurements of scoured wool. *J. Text. Inst. 65*: T281-287.

HOCKING, R.R. (1976). The analysis and selection of variables in linear regression. *Biometrics 32*: 1-49.

HOLDAWAY, H.W. (1965). A theoretical model for predicting the strength of singles worsted yarns. *J. Text. Inst. 56*: T121-144.

HUNTER, L. (1980). The effects of wool fibre properties on processing performance and yarn and fabric properties. *Proc. VI Intern. Wool Text. Res. Confer. 1:* 133-193.

INCE, J. (1976). The search is on for the ideal carpet wool. *Wool Record 130:* 75.

INCE, J. (1978). IWS research: The characteristics of carpet wools in relation to processing and performance. In *Carpet wools - carpet manufacture.* (Ed. Story, L.F.) WRONZ, Christchurch, New Zealand: 59-74.

INCE, J. (1979). Carpets - manufacture to maintenance, engineering of wool carpet yarns. *Text. Inst. Ind. 17*: 23-28.

INCE, J. ; RYDER, M.L. (1984). The evaluation of carpets made from experimental wools. *J. Text. Inst. 75*: 47-59.

JAKUBEC, V.; LINDOVSKY, R. (1968). Heritability of the occurrence of halo-hairs in lambs in relation to productive charcters in adult Merino sheep. *Anim. Breed. Abstr. 37*: No. 3700.

JAMES, J.W. (1982). Construction, uses and problems of multitrait selection indices. *Proc. II World Congr. Genetics applied to Livestock Production, Madrid 5*: 130-139.

JOYCE, J.P. (1961). The cotted fleece. *Proc. of the Ruakura Farmers' Conf. Week*, Hamilton, New Zealand.

LAPPAGE, J.; BEDFORD, J. (1983). The WRONZ medullameter. *WRONZ Report No. 107.*

LARSEN, W. (1978). Wool requirements for woollen tufted carpets. In *Carpet wools - carpet manufacture.* (Ed. Story, L.F.) WRONZ, Christchurch, New Zealand: 19-21.

LOCKART, L.W. (1954). Sampling of fleeces for yield, staple length and crimps per inch measurement. *Aust. J. Agric. Res. 5*: 555-567.

LOCKART, L.W. (1956). Birthcoat of lambs and adult fibre diameter. *Aust. J. Agric. Res. 7*: 152-157.

McCUTCHEON, S.N. (1981). *A study of some factors affecting the resistance of newborn lambs to cold-stress with particular reference to starvation and exposure mortality.* Ph.D. Thesis, Massey University, New Zealand.

McMAHON, P.R. (1937). Methods for the estimation of medullation in wool samples. *J. Text. Inst. 28*: T349-360.

McPHERSON, A.W. (1982). *An appraisal of selection objectives and criteria for New Zealand Romney sheep with particular reference to wool traits.* M. Agric. Sci. Thesis, Massey University, New Zealand.

MERSEREAU, E.P.; RAINARD, L.W. (1951). Color changes in wool during processing. *Text. Res. J. 21*: 239-247.

MORRIS, C.A.; CLARKE, J.N.; ELLIOTT, K.H. (1982). Objectives for sheep improvement. In *Breeding and Reproduction.* (Eds. Wickham, G.W.; McDonald, M.F.) N.Z. Institute of Agric. Sci. 1: 143-167.

MULLANEY, P.D. (1966). The relation of birthcoat and lamb survival. *Aust. J. exp. Agric. Anim. Husb. 6*: 84-87.

NANDURKAR, U.; LAPPAGE, J. (1977). Evaluation of some Drysdale carpet wools: effect of the fleece type of the Romney ewe. *WRONZ Communication No. 48.*

NASH, C.E. (1964). The assessment of *N*-type fleeces. II. The physical properties and practical testing of the finished carpets. *J. Text. Inst. 55*: T309-323.

NZSAP. (1974). Guidelines for wool production in New Zealand. *N.Z. Soc. Anim. Prod., Occasional publication No. 3.*

OBST, J.M.; EVANS, J.V. (1970). Genotype-environment interactions in lamb mortality with particular reference to birthcoat and haemoglobin type. *Proc. Aust. Soc. Anim. Prod. 8*: 149-153.

ONIONS, W.J.; OXTOBY, E; TOWNEND, P.P. (1967). Factors affecting the thickness and compressibility of worsted-spun yarns. *J. Text. Inst. 58*: T293-315.

ORWIN, D.F.G.; WOODS, J.L.; ELLIOTT, K.H. (1980). Composition of the cortex of sound and tender wools. *Proc. VI Intern. Wool Text. Res. Conf., Pretoria,II*: 193-206.

PLANOVSKY, L. (1960). The relation between kemp in the tail of lambs and fineness and uniformity of the wool of Merinos. *Anim. Breed. Abstr. 28:* No. 1381.

POHLE, E.M. (1942). Relationship between weanling and yearling fleece characters in range sheep. *J. Anim. Sci. 1:* 229-235.

POHLE, E.M.; WOLF, H.W.; TERRILL, C.E. (1943). Clean wool yield variation among regions of Rambouillet fleeces. *J. Anim. Sci. 2:* 181-187.

PURSER, A.F.; KARAM, H.A. (1967). Lamb survival, growth and fleece production in relation to birthcoat type among Welsh Mountain sheep. *Anim. Prod. 9:* 75-85.

RAE, A.L. (1958). Genetic variation and covariation in productive characters of New Zealand Romney Marsh sheep. *N.Z. J. Agric. Res. 1:* 104-123.

RAE, A.L. (1982). Objectives in sheep breeding. *Ist World Congr. on Sheep and Beef Cattle Breeding, 1980.* Massey University, New Zealand.

RENDEL, J.M. (1954). Inheritance of birthcoat in a flock of improved Welsh Mountain sheep. *Aust. J. Agric. Res. 5:* 297-304.

ROBERTS, N.F. (1956). The relation between the softness of handle of wool in the greasy and scoured states and its physical characteristics. *Text. Res. J. 26:* 687-697.

ROBERTSON, A. (1959). Experimental design in the evaluation of genetic parameters. *Biometrics 15:* 219-226.

ROSS, D.A. (1950). *Some aspects of medullation and benzol testing in N-type lambs.* M. Agric. Sci. Thesis, Massey Agricultural College, University of New Zealand.

ROSS, D.A. (1970). The Drysdale. *WRONZ Report No. 1.*

ROSS, D.A. (1978a). In *Carpet wools - carpet manufacture.* (Ed. Story, L.F.) WRONZ, Christchurch, New Zealand: 41, 119.

ROSS, D.A. (1978b). Carpet wools - carpet manufacture. *Wool 4:* 25-29.

ROSS, D.A. (1982). Staple length, staple strength, fibre length and processing. *Wool* *7*: 12-15.

ROSS, D.A.; SPEAKMAN, J.A. (1957). The gravimetric estimation of medulla in wool. *Text. Res. J.* *27*: 345-351.

ROSS, D.A.; BRATT, R.L.; STORY, L.F. (1960). The effect of staple strength on carding and combing. *J. Text. Inst.* *51*: T907-921.

ROSS, D.A.; NARSIAN, M.G.; BRATT, R.L.; NOONAN, K.K.; LILICO, D. (1975). An evaluation of Drysdale wool for use in carpet manufacture. *WRONZ Communication No. 32*.

ROSS, D.A.; WICKHAM, G.A.; ELLIOTT, K.H. (1982). Breeding objectives to improve wool used in carpets. *Proc. Ist World Congr. on Sheep and Beef Cattle Breeding, 1980,* Massey University, New Zealand.

ROSS, J.M. (1954). *Kemp in New Zealand Romney N-type fleece.* M. Agric. Sci. Thesis, Massey Agric. College, University of New Zealand.

ROSS, J.M. ; WRIGHT, G.M. (1954). Kemp succession in *N*-type sheep. *Aust. J. Agric. Res. 5*: 503-510.

ROUGEOT, J. (1961). Comparative influence of annual and half-yearly periodic variations in daylight length on the follicular cycles of short kemp in the fleece of Limousin ewes. Relation with the reproductive cycle. *Anim. Breed. Abstr. 31*: No. 1226.

ROUGEOT, J.; ALLAIN, D.; MARTINET, L. (1984). Photoperiodic and hormonal control of seasonal coat changes in mammals with special reference to sheep and mink. *Acta Zool. Fennica* ***171***: 13-18.

RUDALL, K.M. (1955). The size and shape of the papilla in wool follicles. *Proc. Intern. Wool Text. Conf. Aust.* ***F***: F9-25.

RUDALL, K.M.; WICKHAM, G.A. (1965). Development of wool follicles and fibres on autoplastic grafts of stored foetal lamb skin. In *Biology of the skin and hair growth.* (Eds. Lyne, A.G.; Short, B.F.) Angus & Robertson, Sydney, Australia: 75-88.

RYDER, M.L. (1969). The development and structure of, and seasonal change in, the coat of some Wiltshire sheep. *Anim. Prod. 11*: 467-477.

RYDER, M.L. (1973). Variation in the birthcoats of Wiltshire lambs, and its relation to casting of the adult fleece. *J. Agric. Sci., Camb.* ***80***: 71-74.

RYDER, M.L. (1974). The birthcoat of lambs. *Anim. Breed. Res. Orgn. Report 1974*: 33-39.

RYDER, M.L.; STEPHENSON, S.K. (1968). *Wool growth.* Academic Press, London.

SCHINCKEL, P.G. (1951). Birthcoats of Australian Merino lambs. *Nature 168*: 698.

SCHINCKEL, P.G. (1955). Inheritance of birthcoats in a strain of Merino sheep. *Aust. J. Agric. Res. 6*: 595-607.

SCHINCKEL, P.G. (1958). The relationship of lamb birthcoat to adult fleece structure in a strain of Merino sheep. *Aust. J. Agric. Res. 9*: 567-578.

SEARLE, S.R. (1970). *Linear Models.* John Wiley and Sons, Inc., New York, London, Sydney, Toronto. 532 pp.

SEMMENS, T.D. (1971). Birthcoats in lambs. *Tasmanian J. Agric. 42*: 253-258.

SCHOTT, R.G.; POHLE, E.M.; SPENCER, D.A.; BRIER, G.W. (1942). Wool yields in the small side-sample as related to individual whole-fleece yields in four breed-groups of sheep. *J. Anim. Sci. 1*: 137-144.

SHAH, S.M.A.; WHITELEY, K.J. (1971). I. The influence of fibre characteristics on the tactile appraisal of loose wool. *J. Text. Inst. 62*: 361-374.

SIDE, H.J.A. (1964). *Fibre growth rate changes in foetus, lamb and ewe.* Ph.D. Thesis, Leeds University, U.K.

SIDE, H.J.A.; RUDALL, K.M. (1964). Rates of hair growth. In *Progress in the biological sciences in relation to dermatology.* (Eds. Rook, A.; Champion, R.H.) Cambridge University Press; 337-354.

SKARMAN, S.; NOMMERA, E. (1955). Tail of lamb - fleece of adult: A study of the correlation between the amount of coarse and medullated hairs on the tail of Cheviot lambs and the wool quality of sheep when grown up. *Kungl. Landbrukshogskolans Annaler 22*: 243.

SLEE, J. (1959). Fleece shedding, staple length and fleece weight in experimental Wiltshire Horn X Scottish Blackface sheep crosses. *J. Agric. Sci., Camb. 53*: 209-223.

SLEE, J. (1965). The genetics of hair growth. In *Comparative physiology and pathology of the skin.* (Eds. Rook, A.J.; Walton, G.S.) Blackwell Scientific Publications, Oxford, U.K.: 103-118.

SNEDECOR, G.W.; COCHRAN, W.G. (1980). *Statistical Methods*. 7th ed. Iowa State University Press, Ames, Iowa, U.S.A.

SRIVASTAVA, T.V.K.; ONIONS, W.J.; TOWNEND, P.P. (1976). Some factors affecting the hairiness of worsted-spun yarns. *J. Text. Inst.* *67*: T447-455.

STEPHENSON, S.K. (1952). *Some aspects of gene dosage effects in N-type sheep.* M. Agric. Sci. Thesis, Massey Agric. College, University of New Zealand.

STEPHENSON, S.K. (1956). Some aspects of gene dosage in *N*-type sheep. *Aust. J. Agric. Res.* *7*: 447-468.

STEPHENSON, S.K. (1958). Wool follicle development in the New Zealand Romney and *N*-type sheep. II. Follicle population density during foetal development. *Aust. J. Agric. Res.* *9*: 138-160.

STEPHENSON, S.K. (1959). Wool follicle development in New Zealand Romney and *N*-type sheep. III. The diameters of follicles and fibres. *Aust. J. Agric. Res.* *10*: 108-120.

SUGAI,K.; YUHARA, M. (1954). The lamb's tail wool in relation to wool type in the Corriedale sheep. III. The wool length of the lamb's tail in relation to the wool length of the other body regions. *Sci. Report. Faculty of Agric., Okayama Univ., Japan No. 5:* 33-39.

SUMNER, R.M.W. (1969). *A comparative study of the effects of two stocking levels on wool follicle development and wool production of the New Zealand Romney sheep.* M. Agric. Sci. Thesis, Massey University, New Zealand.

SUMNER, R.M.W.; REVFEIM, K.J.A. (1973). Sources of variation and design criteria for wool fibre diameter measurements for New Zealand Romney sheep. *N.Z. J. Agric. Res.* *16*: 169-176.

SUTHERLAND, J.A. (1939). *A study of the plateau array.* M. Agric. Sci. Thesis, Massey Agric. College, University of New Zealand.

TEASDALE, D.C. (1984). Standards for measurement of wool colour. *Wool Technol. Sheep Breed.* *32*: 171.

THORNBERRY, K.J.; ATKINS, K.D. (1984). Variation in non-wool components of greasy fleece over the body of Merino sheep. *Aust. J. Exp. Agric. Anim. Husb.* *24*: 72-76.

TOLDT, K. (1910). Uber eine beachtenswerte Haarsorte und uber das Haarformensystem der Saugetiere. *Ann. Naturch. Hofmus (Wien), 1910:* 24-265.

OLDT, K. (1912). Beitrage zur kenntnis dere Behaarung der Saugetiere. *Zool. Jb. Syst. 33*: 9-50.

OLDT, K. (1935) Aufban und naturliche Farbung des Haarkleides der Wildsaugetiere. *Deutsche Gessellschaft für Kleintier und Pelztierzucht,* G.m.b.H. and Co., Leipzig, 219 pp.

RIPATHY, L.P. (1966). *Estimation of important genetic and phenotypic parameters of some productive traits in the New Zealand Romney Marsh sheep.* M. Agric. Sci., Thesis, Massey University, New Zealand.

URNER, H.N. (1956) Measurement as an aid to selection in breeding sheep for wool production. *Anim. Breed. Abstr. 24:* 87-118.

URNER, H.N. (1976). Methods of improving production in characters of importance. *Proc. Intern. Sheep Breeding Congr., Muresk, Australia.* (Eds. Tomes, G.J.; Robertson, D.E.; Lightfoot, R.J.).

URNER, H.N.; YOUNG, S.S.Y. (1969). *Quantitative Genetics.* Macmillan of Australia, 332 pp.

URNER, H.N.; DUNLOP, A.A. (1974). Selection for wool production. *Proc. Ist World Congr. on Genetics applied to Livestock Production, Madrid 1*: 739-756.

AN WYKE, C.M. (1946). A study of the compressibility of wool, with special reference to South African Merino wool. *Onderstepoort J. Vet. Sci. Anim. Indust. 21:* 99-226.

ON BERGEN, W. (1963). What the manufacturer requires in raw wool. *Wool Technol. Sheep Breeding 10:* 43-49.

HEELER, J.L.; HEDGES, D.A.; MULCAHY, C. (1977). The use of dyebanding for measuring wool production and fleece tip wear in rugged and unrugged sheep. *Aust. J. Agric. Res. 28:* 721-735.

HITELEY, K.J.; WATSON, N.R.; WILKINS, O.D. (1978). The relationship between the resistance to compression of wool bulks and follicle curvature. *J. Text. Inst. 69:* 41-48.

HITELEY, K.J.; CLARK, M.J.; WELSMAN, S.J.; STANTON, J.H. (1980). Observations on the characteristics of Australian greasy wool. II. Colour in Merino fleece wools. *J. Text. Inst. 71:* 177-188.

HITELEY, K.J.; JACKSON, N. (1982). Breeding for apparel wool. *Proc. Ist World Congr. on Sheep and Beef Cattle Breeding, 1980,* Massey University, New Zealand.

CKHAM, G.A. (1958). *A study of the follicular origin of the fibre types of N-grade Romney lambs.* M. Agric. Sci., Thesis, Massey Agricultural College, University of New Zealand.

WICKHAM, G.A. (1963). *Factors determining the structure of the fleece of sheep with special reference to pre-natal effects.* Ph.D. Thesis, Leeds University, U.K.

WICKHAM, G.A. (1966). What emphasis should be placed on wool characters when selecting for sheep? *Sheepfarming Annual 1966*: 95-103.

WICKHAM, G.A. (1973). Selection criteria for wool improvement by sheep breeding. *Discussion paper for N.Z. Soc. Anim. Prod. Wool Study Group.* 32 pp.

WICKHAM, G.A. (1977 - unpublished). Problems of defining Drysdale wool quality. *Paper presented to Ministry of Agric. Fish. Sheep and Beef Officers Annual Conference,* Wellington, New Zealand.

WICKHAM, G.A. (1978). Development of breeds for carpet wool production in New Zealand. *World Review Anim. Prod.* ***14***: 33-40.

WICKHAM, G.A. (1982). Selection criteria for young animals being mated early in life and genetic implications of early breeding. *New Zealand Agric. Sci.* ***16***: 110-112.

WICKHAM, G.A.; BIGHAM, M.L. (1976). Growing more and better wool. *Proc. Ruakura Farmers; Conference,* Hamilton, New Zealand.

WICKHAM, G.A.; RAE, A.L. (1977). Investigations of carpet wool genes in sheep. *Proc. N.Z. Soc. Anim. Prod.* ***37***: 213-217.

WICKHAM, G.A.; McPHERSON, A.W. (1985). A review of the importance of wool traits as genetic improvement objectives and selection criteria for New Zealand Romney sheep. *Proc. N.Z. Soc. Anim. Prod.* ***45***: 203-208.

WIGGINS, L.K. (1976). New criteria for wool selection. *Wool Record* ***129***: 81-83.

WILCOX, J.C. (1968). Relationship between birthcoat and various characteristics in the Welsh Mountain sheep. *Expl. Husb.* ***17***: 59-69.

YOUNG, S.S.Y.; CHAPMAN, R.E. (1958). Fleece characteristics and their influence on wool production per unit area of skin in Merino sheep. *Aust. J. Agric. Res.* ***9***: 363-372.